THE PROCEEDINGS

OF THE

SECOND MALAYSIAN SOIL CONFERENCE

HELD IN FEBRUARY 1966,

KUALA LUMPUR, MALAYA,

MALAYSIA.

ORGANISED BY

THE RESEARCH BRANCH,

DIVISION OF AGRICULTURE,

MINISTRY OF AGRICULTURE & CO-OPERATIVES,

KUALA LUMPUR, MALAYSIA.

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THE PROCEEDINGS OF THE SECOND MALAYSIAN SOIL CONFERENCE

HELD IN FEBRUARY 1 9 6 6

K U A L A L U M P U R

M A L A Y A.

edited by

NG SIEW KEE
IGNATIUS WONG FEN THAU
LAW WEI MIN.

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MENTERI PERTANIAN DAN SHARIKAT KERJASAMA, YANG BERHORMAT TUAN HAJI MOHD. GHAZALI BIN HAJI JAWI, MEMBUKA PERSIDANGAN II AHLI2 SAINS TANAH MALAYSIA PADA PUKUL 10.00 PAGI HARI SABTU 12HB. FEBRUARI, 1966 DI-DEWAN MESHUARAT JABATAN PERTANIAN, KUALA LUMPUR

Dato' Setia Usaha Tetap,
Ketua2 Bahagian dalam Kementerian Pertanian dan Sharikat Kerjasama,
Tuan2,

Saya berasa bertuah kerana dapat bersama2 tuan2 pagi hari ini, dan beruchap serta meresmikan Persidangan kedua bagi Ahli Sains Tanah Malaysia. Benarkan-lah saya kesempatan mengalu2kan peserta2 dari negeri2 Sabah dan Sarawak khas-nya ka-Tanah Besar Malaysia, sambil mengharap bahawa kedatangan mereka2 ini bukan sahaja memberi sumbangan dalam persidangan ini, tetapi juga sabagai satu peluang melihat dari dekat akan ranchangan luar bandar yang kedua, yang telah selesai akhir tahun sudah.

Saya di-beritahu bahawa Persidangan pertama Ahli2 Sains Tanah Malaysia telah di-adakan di-Sabah pada bulan Februari, 1964. Walaupun harus beberapa kesulitan yang telah di-hadapi pada waktu itu, saya anggap persidangan pertama itu mendapat kejayaan bukan sahaja bagi mengumpulkan Ahli2 Sains Tanah bersama2, tetapi tentu-lah juga dapat meletakkan beberapa asas dan prinsip2 yang berkenaan dengan Sains Tanah, satu2 bidang sains yang semakin bertambah penting-nya di-negeri2 panas, saperti Malaysia yang menghadapi renchana2 pengembangan pertanian. Saya yakin bahawa kejayaan2 dari Persidangan Pertama itu telah menguatkan keazaman bagi mengadakan persidangan ini. Saya juga yakin bahawa kejayaan pertama dahulu itu telah menggalakkan perkembangan bidang sains ini, sabagai yang dapat di-saksikan dari perkara2 yang akan di-binchangkan dalam persidangan kedua ini.

Saya mengambil kesempatan menguchap tahniah kapada seluroh pegawai yang mengasas persidangan ini yang telah mendapat sambutan yang baik dari beberapa pehak.

Persidangan tuan2 yang di-jadualkan memakan masa selama 16 hari itu, termasok-lah lawatan2 kapada beberapa tempat di-Tanah Melayu ini, selain dari pertukaran2 fikiran dan pendapat2 dari beberapa laporan yang akan di-bentangkan, Saya berharap bahawa lawatan2 keluar akan memberi peluang kapada peserta2 dari Malaysia Timor memerhati ka-kawasan2 luar bandar Tanah Melayu.

Oleh kerana persidangan ini di-adakan di-Tanah Melayu, maka dapat-lah sa-jumlah besar pegawai2 tempatan mengambil bahagian. Peserta2 tempatan bukan-lah hendak-nya dari Ahli2 Sains Tanah sahaja, tetapi juga dari lain2 bidang sains dalam Jabatan Pertanian. Saya harap pegawai2 agronomi serta ahli2 kaji-tumbohan akan turut berserta, dalam persidangan ini, kalau pun bukan sabagai peserta active tetapi sabagai pemerhati2. Dan lagi persidangan kali ini tentu-lah memberi peluang bagi lebeh banyak peserta dari Universiti dan Kolej Pertanian serta badan2 penyelidekan saperti Pusat Penyelidekan Getah (RRIM). Dengan kehadziran sa-jumlah besar ahli2 sains tanah yang mempunyai pengetahuan dan kemahiran dalam tanah dan keadaan2 tanah, saya yakin persidangan kedua ini akan mendapat kejayaan yang lebeh besar.

Pada hemat saya, tanah hendak-nya jangan-lah memjadi persoalan ahli2 sains tanah semata2, tetapi sa-balek-nya ia-lah persoalan semua - termasok-lah ahli2 sains, pendidekan, ekonomi, meshuarat kerajaan, peranchang, pertanian dan seterus-nya peladang2. Pendapat saya ini berasas kapada wujud-nya tanah sabagai kekayaan negara yang

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kita semua sabagai warga negara mempesakai. Pada ka-biasaan-nya, kita tak sedar bahawa tanah itu satu benda hidup sebab ia mempunyai asal dan berubah. Tanah juga oleh sebab keadaan2 yang tertentu boleh menjadi "mati" dan binasa. Sabagai benda hidup, penting-lah tanah di-pelihara dan di-beri "makan" supaya kekal kesuboran-nya. Saya harap kita semua akan berikhtiar memelihara tanah yang kita pusakai itu. Oleh itu saya berkata tanah ia-lah persoalan semua warga negara, dan ada-lah satu kekayaan kita ini. Bagi mengenali tanah kita, kita di-Tanah Melayu, telah menitek beratkan soalan pemereksaan tanah atau soil survey. Ranchangan ini telah di-perbesarkan dalam masa 5 tahun yang lepas dan akan di-kuatkan juga dalam Ranchangan 5 tahun Pertama ini. Ranchangan ini ia-lah asas atau permulaan bagi ranchangan2 kemajuan pertanian di-masa hadapan. Di-mana2 juga di-dunia ini, di-mana ranchangan pertanian di-jalankan atau pun di-mulakan, maka sumbangan ahli2 sains tanah untok memereksa tanah ada-lah di-hargai sekali. Begitu juga kita di-Malaysia, bagi ranchangan2 saperti yang di-jalankan oleh Lembaga Kemajuan Tanah Persekutuan, maka permulaan-nya ada-lah penyertaan ahli2 sains tanah sebelum kerja2 membuka tanah di-mulakan, Kejayaan ranchangan kemajuan tanah kita ada-lah berasas dari kebijaksanaan pemilehan kawasan2 yang bergantong kapada keadaan2 tanah.

Ada setengah2 pehak di-negeri ini yang hingga masa ini pun belom lagi sedar betapa penting-nya sains tanah, terutama sekali pemereksaan tanah (soil survey). Pehak2 ini kerap kali-nya mendesak supaya kawasan2 yang belom di-buka itu hendak-lah lekas di-buka untok pertanian dan jangan-lah di-biarkan dalam keadaan hutan. Begitu juga ada pekah2 yang menuntut bahawa tanah2 sa-patut-nya di-keluarkan dengan tak payah di-adakan soil survey dahulu. Saya fikir sangat-lah penting bagi kita mempertahankan berjaya-nya tuntutan2 tadi kerana membenarkan tuntutan2 itu berarti menjemput benchana besar.

Walaupun begitu, saya puas hati kerana sa-bahagian besar dari ra'ayat2 kita terutama sekali yang bertanggong jawab dalam bidang perkembangan pertanian sangat-lah sedar betapa penting-nya soil survey sebelum satu kawasan hutan itu di-buka untok pertanian. Pendek-nya pehak ini tidak hendak membuat apa2 kechuali sa-telah mendapat surat kenyataan atas keadaan tanah (Soil Suitability C Certificate). Sedang soil Survey ini telah mendapat perhatian, namun bidang sains ini tersangat muda di-negara kita ini. Jadi perkhidmatan saperti ini hanya-lah di-adakan oleh Kerajaan semata2 dan barang siapa berkehendakkan perkhidmatan ini maka mustahak-lah ia mendapati-nya dari jabatan yang tertentu.

Saya tidak-lah menghalang bahawa soil survey harus di-jalankan oleh sharikar2, tetapi pada permulaan-nya saperti di-negara kita, waktu ini penting-lah kerja ini di-jalankan oleh jabatan Kerajaan, kerana pada masa ini kita sedang menyediakan ranchangan2 kemajuan ekonomi yang berdasarkan pertanian. Ranchangan ini hanya dapat di-adakan dengan ada-nya pengetahuan2 mengenai tanah di-merata2 tempat di-negeri ini. Maka apabila segala pengetahuan2 itu di-perdapati baru-lah shor2 tertentu di-perbuat bagi kemajuan di-masa hadapan.

Chawangan Sains Tanah dari Jabatan Pertanian sedang di-per-besarkan. Saya sukachita bahawa pada waktu ini telah ada beberapa orang ahli2 sains tanah tempatan, Ada-lah menjadi dasar Kementerian untok memperbesarkan lagi chawangan ini, dengan mengadakan beberapa banyak biasiswa untok pelajar2 tempatan. Saya harap dalam masa beberapa tahun lagi chawangan ini akan mempunyai pegawai2 yang lengkap.

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Walau pun Chawangan Sains Tanah ini muda, saya berani berkata bahawa ia telah matang dan telah pun mendapat beberapa banyak kejayaan. Misal-nya di-Pahang kawasan Jengka seluas 200,000 ekar telah di-pereksa oleh Chawangan Sains Tanah kita. Biar-lah pun survey ini sechara "kasar" tetapi walau pun begini, ada-lah sangat berguna, kerana dari survey ini dapat-lah di-adakan satu peta tanah bagi kawasan tersebut sabagai permulaan bagi memajukan-nya. Saya faham, hingga akhir tahun 1965, sa-banyak 76 peratus kawasan di-Tanah Melayu telah siap di-pereksa. Kapada seluroh ahli2 sains tanah yang telah bekerja sechara senyap saya mengambil peluang ini menguchap tahniah dan terima kaseh atas kerja yang telah di-jalankan. Saya tak shak lagi bahawa kejayaan yang sama banding-nya telah juga di-dapati di-Sabah dan di-Sarawak.

Tuan2,

Saya sedar bahawa soil survey hanya-lah permulaan, tetapi sains tanah tidak-lah berarti soil survey semata2. Selepas soil survey di-jalankan dan selepas tanah di-buka untok pertanian, maka penyelidekan mustahak-lah di-jalankan bagi mendapatkan chara2 bagaimana dapat di-kekalkan tanah dalam keadaan yang baik. Saya harap ikhtiar ini tidak-lah hendak-nya di-abai2kan, kerana apabila kita berhenti memelihara tanah, maka tanah juga tidak berbakti kapada kita lagi. Oleh itu perkara ini mustahak-lah di selenggarakan kira-nya kita berkehendakkan mengekalkan atau menambah pengeluaran hasil pertanian.

Tuan,

Malaysia pada 'am-nya dan Tanah Melayu khas-nya ada-lah negeri yang kekurangan makanan. Sabagai sa-orang yang bukan pakar, penghasilan makanan dapat di-perbanyakkan dengan membuka tanah baru. Tetapi hendak-lah kita ingat bahawa tanah baru yang dapat di-buka ada-lah terhad, dan selain dari ini belanja membuka tanah baru itu tersangat tinggi. Jadi kita juga terpaksa mengikut negera2 lain dalam ikhtiar menambah penghasilan pertanian dengan jalan memperbaiki tanah. Saya harap pengeluaran dari tanah dengan menggunakan sains tanah di-beri pertimbangan oleh persidangan tuan2.

Ada beberapa aspek tanah yang patut di-selenggarakan apabila kita mempunyai pegawai yang berkelayakkan. Aspek2 microbiology dan clay mineralogy dan sebagai-nya yang penting dalam sains tanah, saya perchaya belom di-selenggarakan. Saya harap aspek2 ini tidak di-keluarkan dari ranchangan penyelidekan yang bakal di-jalankan dari sekarang.

Tuan2 hanya mempunyai sadikit masa sahaja pagi ini sebelum bertolak ka-Kota Bharu untok memulakan lawatan tuan2. Saya tidak-lah hendak mengambil masa tuan yang berharga itu, tetapi sebelum tuan2 berpisah dari sini, saya ingin mengakhiri dengan do'a agar persidangan kedua Sains Tanah Malaysia ini berjaya. Saya juga berdo'a mudah2an Persidangan kedua ini akan di-ikuti dengan beberapa banyak persidangan menganai masa'alah tanah, hingga dapat kita menchapai kemajuan pesat dalam bidang sains tanah,

Dengan sukachita-nya saya ishtiharkan Persidangan Kedua Sains Tanah di-buka.

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Speech of the Minister of Agriculture & Co-operatives, Tuan Haji Mohd. Ghazali bin Haji Jawi, at the opening of the Second Malaysian Soils Conference in Kuala Lumpur on Saturday, 12th February, 1966, at 10.00 a.m.

It is indeed a privilege for me to be able to be here with you this morning and to address and declare open the Second Malaysian Soil Conference. If I may be permitted, I would wish to take this early opportunity to welcome in the first instance the participants from the States of Sabah and Sarawak especially to the mainland of Malaysia and to wish that they not only have a useful stay here but also have an excellent opportunity to look at the rural development programme that was implemented in Malaysia under the Second Five Year Plan which ended only at the end of last year.

I have been informed that the First Malaysian Soil Conference was held in Sabah in February, 1964. In spite of the many possible limitations, the first conference was undoubtedly a successful one, not only in bringing together those scientists connected with soil science but also in establishing the many bases and principles common to the discipline which is growing in significant importance to any tropical country like ours in the course of Agricultural development. I feel sure that the success of the first conference has given confidence and encouragement towards the organisation of this second conference. I am equally sure, you will agree with me, that the first success led to rapid development in the discipline as testified by the number of fields to be covered during the current conference.

I wish to congratulate the organisers of this conference which has been given enthusiastic reception by all interested in Soil Science.

Your conference which is scheduled to last 16 days will, I understand, include field trips to many parts of the country together with normal discussions on papers which, I believe, have been submitted by the various participants. I hope that the field trips would offer an opportunity to the participants from East Malaysia to see the rural areas of West Malaysia.

The fact that your second conference is being held in Malaya is of particular interest to us because it offers greater opportunities for more of our local officers to participate, not necessarily from among the soil scientists but from other disciplines within the Department of Agriculture. I hope that the officers such as agronomists and plant breeders would also join in the conference if not as active participants but at least as keen observers. The fact that you are having your conference in this part of the country would also offer increased participation by educational and other institutions such as the University of Malaya, the College of Agriculture and the Rubber Research Institute of Malaya. With this large number of people who are specialists in soil science and with their intimate knowledge of soils and soil conditions in this part of the country, I have little doubt that your second conference would indeed be a bigger success.

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In my opinion, soils as a whole should not be the sole interest of soil scientists but they should be the concern of all - scientists, educators, economists, legislators, planners, agriculturists and farmers. I feel so, simply because soil is the only wealth of the country that we all as a nation commonly inherit. More often than not, we fail to recognise that soil is essentially a living thing in the sense that it originates, develops and grows, and this growth together with its development is subjected to conditions that may kill or destroy it. As a growing thing, therefore, it needs to be protected and nourished if it is to survive. I hope that we shall protect the good soil that we have inherited. Therefore, I say again that soil is the concern of everyone and it is a wealth that should be recognised and protected by every citizen.

While recognising the importance of soil, it is nevertheless of importance also that before anything could be done to protect and maintai our resources, we have, as in any other case, to recognise this wealth of ours. To this end, therefore, we in this part of the country have laid emphasis on soil survey - a programme which was expanded during the last Five-Year Development Plan and which will continue to be emphasised durin the current Five-Year Plan. It is a programme which, I must say, forms th basis or the starting point of the future agricultural development of the country. In any part of the world where agricultural development projects are being implemented or planned, the role of soil scientists in soil survey has been placed in a most prominent position. With us in Malaysia particularly in our agricultural development planning such as for the Federal Land Development schemes, it is the soil surveyors who are first consulted and it is their work which has first to be completed before any physical development could be carried out. I can say for sure that the success of our land development schemes has been based largely on the wis choice of sites and areas from the point of view of soil conditions.

There are certain sectors in this country which until now have failed to recognise the importance of soil science, particularly with regard to soil survey. It is surprising to note the sweeping expressions made by various people to the effect that undeveloped parts of the countr should not remain under forest but should be developed for agriculture. There are also certain sections which are of the view that soil survey is not important in so far as land alienation is concerned. There have been suggestions that in order to speed up agricultural development, land shoul be alienated irrespective of whether the area has been soil-surveyed or not. I think we have got to safeguard against this sort of approach to land alienation and development because it is leading to national catastro

Nevertheless, I am very pleased to note that a large number of our people who are responsible for agricultural development are fully aware of the importance of soil survey before any development is carried out and, in more cases than not, there is a demand for a certificate of soil suitability of the area. However, while the importance of soil survey is recognised, the soil survey itself is a new service to this country - one that is not provided by any private institution - and, therefore, whoever is interested in soil survey work being carried out should depend on the service that can be offered by the Government Departments.

While I am not opposed entirely to the soil survey being carried out by private organisations, I am of the view that this responsibilty at this initial stage should be vested in a proper Government agency, especially set up for this purpose simply because we are now at the stage of preparation of our Economic Development Plan based on agriculture. To do so, we have to collect all the information regarding soil potentialiti in the various parts of the country and it is only after such information and data have been assembled that specific recommendations should be made for the future development programme.

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Our Soil Science Division of the Department of Ariculture is growing and I am happy to say that we have now a number of local officers who are devoted to soil science and soil survey work. It is our policy to continue to expand this important division and towards this end, we now have a number of local young men being trained at various institutions for service in this division. I hope that within the next few years, the Division would strengthened to its expected size.

In spite of the fact that the Soil Science Division is young in age, I dare say that it has matured in experience and has vast work to its credit. For instance, the Jengka Triangle in Pahang covering an area of over 200,000 acres was soil-surveyed by the Soil Science Division. Admittedly, the survey was on a large scale basis but it has nevertheless enabled the preparation of an appropriate soil survey map of that area for the projected development plan. I am given to understand that by the end of 1965, about 76% of the total area of Malaya would have been covered by reconnaissance soil survey. In this survey will be included considerable acreage of land of agricultural potential. To the soil survey personnel who have been working more or less behind the scene I wish to take this opportunity to extend my hearty congratulations on the work that they have done. I have no doubt also that a similar achievement has been made by the soil surveyors in both Sabah and Sarawak.

Gentlemen, I also understand that soil survey work is only beginning but soil science as a whole is not ending with this. I am sure that after soil survey and after agricultural development in any particular area, continued research has to be carried out concerning the measures to be taken to guarantee the survival of our soil to which I referred earlier. This aspect of work, I am sure, is not going to be relegated to a second place because as a layman, I think once you stop taking care of soils, the soils will also stop taking care of you. So, it is vital that this aspect of soil management be taken up seriously if we are going to continue to increase or at least maintain our agricultural production at a high level.

Gentlemen, Malaysia, as a whole, and Malaya in particular, as you are aware, is a food deficit area. As a layman, I can say that food production can be increased by the opening up of new land. Nevertheless, there is eventually a limit to this, apart from the high costs and, like any other country in the world, we will have to increase the productivity of our soils. I hope the productivity of our soils through the application of Soil Science would be taken up by your current conference.

There are, of course, other aspects of soils which have to be gone into but this will depend on the trained personnel that we have available in this country. For instance, soil microbiology, and clay mineralogy which are both important in soil science, I believe, have not been gone into by our soil science research in this country. It is my hope that this would not be overlooked and that plans for such research should be made from now.

Gentlemen, you have very limited time this morning as you will be leaving immediately for Kelantan to begin your field tour. I do not, therefore, wish to take up much of your precious time now but before you go away, I wish you all success in the deliberations of your second Soil Science Conference. I also pray that this second conference will be followed by more conferences on this important subject, to move forward in the cause of advancement of soil science in this country.

I take pleasure in declaring the Second Malaysian Soils Conference open.

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PROGRAMME OF CONFERENCE

DATE	EVENT
February 12th	Conference officially declared open in Kuala Lumpur by the Honourable Minister of Agriculture and Co-operatives, Tuan Haji Ghazali b. Jawi.
February 13th-19th	Field excursions to States of Kelantan, Trengganu and Pahang.
February 21st-23rd	Conference Sessions in Kuala Lumpur.
February 24th-26th	Field excursion to States of Malacca and Johore.
February 27th	End of Conference.

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LIST OF PARTICIPANTS

DELEGATES

SABAH

Department of Agriculture

Mr. E.A. Wyrley-Birch
Dr. Shao Yen Tze
Mr. P. Thomas

SARAWAK

Department of Agriculture

Mr. Ahmad b. Haji Ebon
Mr. J.P. Andriesse
Mr. J.M. Bailey
Mr. Lim Chin Pang
Mr. I.M. Scott
Mr. B.J. Watson

STATES OF MALAYA

Department of Agriculture

Mr. Chin Kim Wah
Mr. J. Dumanski
Mr. D.W. Ives
Mr. K. Kanapathy
Mr. Law Wei Min
Mr. M.L. Leamy
Dr. Ng Siew Kee
Mr. S. Paramanathan
Mr. H.A. Smallwood
Mr. S. Thamboo
Mr. T. Wagner
Mr. Ignatius Wong Fen Thau

Rubber Research Institute

Dr. M.M. Guha
Mr. E. Pushparajah
Mr. Mohinder Singh
Mr. Yeow Kheng Hoe

University of Malaya

Mr. Chua, H.H.

E.P.U. Prime Minister's Department

Mr. W.P. Panton

OBSERVERS (STATES OF MALAYA)

Department of Agriculture

Mr. Xavier Nathan
Miss. Chin Nyeok Yoon
Miss. D. Sivaram
Miss. Tai, H.L.
Mr. Cheah Theam Eng
Mr. Nuruddin b. Ma'arof
Mr. K. Selvadurai
Mr. Soo Swee Weng
Mr. Hassan b. Aziz
Mr. Ooi Cheng Hock

Federal Land Development Authority

Mr. K. Balakrishnan

Forest Research Institute, Kepong

Mr. Freezaillah

Rubber Research Institute

Mr. Tan Teo Kim
Mr. Lim Bock Tong
Mr. Cho Shue Nam
Mr. Tan Kwang Jin

Oil Palm Research Station, Banting (Harrisons & Crosfield)

Mr. Hew Choy Kean
Mr. Tam Tai Kin

SESSIONS AND LIST OF PAPERS PRESENTED

Session A — Soil Classification

(1) " Provisional Soil Map of Sabah" by P. THOMAS & A.W. ALLEN.

(2) "A Classification of Sarawak Soils" by Soil Survey Staff, Sarawak, presented by I. Scott.

(3) "Soil Classification in Malaya" by M.L. LEAMY.

(4) "A Scheme for the Classification of Malayan Soils" by K.T. JOSEPH read by Dr. NG SIEW KEE.

(5) "Laboratory Data and Classification of Malayan Soils" by NG SIEW KEE.

Session B — Soil Genesis

(1) "Factors Involved in the Genesis of Some Shale Derived Soils in Malaya" by LAW WEI MIN and M.L. LEAMY.

(2) "A Weathering Sequence on Malaysian Soils Derived from Basic Effusive Rocks" by D.W. IVES.

Session C — Soil Suitability and Land Capability Classification

(1) "Land Capability Classification in the States of Malaya, Malaysia" by W.P. PANTON.

(2) "The Classification and Evaluation of Land in Sarawak" by J.P. ANDRIESSE.

(3) "Soil Suitability Classification for Dryland Crops in Malaya" by IGNATIUS WONG.

Session D — Soil Fertility and Plant Nutrition

(1) "A New Technique of Evaluating Phosphate Fertility in Soils" by SHAO,Y.T.

(2) "Content of Major Nutrients in Rubber-Growing Soils of Malaya" by M.M. GUHA and YEOW KHENG HOE.

(3) "Chemical and Agronomical Studies of a Common Upland Soil in Sarawak" by J.M. BAILEY.

(4) "The Effect of Soils and Fertilisers on the Yield of Rice and the Chemical Composition of the Rice Leaves" by J.M. BAILEY.

(5) "Prospects of Plant and Soil Analysis in Assessing the Fertiliser Requirements of the Oil Palm in Malaya" by NG SIEW KEE & S.THAMBOO

(6) "Responses to Fertilisers in Hevea Brasiliensis in relation to Soil Characteristics" by M.M. GUHA and E. PUSHPARAJAH.

Session E — Problem Soils

(1) "Stranded Beach Soils - A Problem in Sabah" by P. THOMAS.

(2) "Acid Swamp Soils and Problems in their Utilization" by K. KANAPATHY.

(3) "Brown loams and nutrition disorders in cocoa" by A.W. ALLEN and read by E.A. Wyrley-Birch.

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Session A. - Soil Classification

Chairman: W. P. Panton.

(1) "Provisional Soil Map of Sabah"
by P. Thomas and A.W. Allen.

(2) "A Classification of Sarawak Soils"
by Soil Survey Staff, Sarawak
presented by I.M. Scott.

(3) "Soil Classification in Malaya"
by M.L. Leamy.

(4) "A Scheme for the Classification of Malayan Soils"
by K.T. Joseph
presented by Ng Siew Kee

(5) "Laboratory Data and Classification of Malayan Soils"
by Ng Siew Kee.

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A PROVISIONAL SOIL MAP OF SABAH

by

P. Thomas and A.W. Allen

Department of Agriculture, Sabah.

Introduction.

Soil Surveys were carried out in Sabah by commercial organisations during the earlier part of this century, but the records of these investigations are no longer available. Systematic soil surveys in Sabah commenced in 1953 when two officers, Mr. T.R. Paton and Mr. A.W. Allen were appointed to the Department of Agriculture, the former with special responsibility for the volcanic area comprising the Semporna Peninsula, the latter specifically concerned with the West Coast and Interior Residencies and charged with the task of survey investigations in order to expand areas under wet padi. This work involved surveys of the large interior plains of Sabah of which the field work at Keningau, Tambunan, Ranau and Sook was completed by 1959. Subsequently the Melalap-Kemabong plain and part of the large Penawan plain have been completed. Mr. Paton's field work was completed in 1959 and a memoir published in 1962.

2. In 1957, partly as a result of a geological survey of the Labuk Valley carried out by Dr. F.H. Fitch, subsequently Director of the Geological Survey Department, and of preliminary traverses by Mr. A. W. Allen, a full scale survey was launched in this valley. In view of the interest this survey aroused, assistance from U.N. Special Fund was requested and in 1962, a team, which included two soil scientists Mr. D. Ives and Mr. A.J. Hooper amongst its members, took over this work. It completed its report by the end of 1964.

3. In 1962, the Darvel Bay and Segama valley area was selected as a major survey area, this survey being entrusted to Mr. P. Thomas who had recently joined the Department, and is now responsible for all soil survey work throughout the State.

4. In 1964, two graduate members of the Voluntary Service Overseas organisation, Mr. R.G. Barber and Mr. D. McCredie were attached to the Department and the former allocated special areas around Sandakan Harbour and parts of Labuk bay, the latter being posted to the Interior to take over a survey of the Penawan Plain from Mr. Allen.

5. In the meantime training of local staff had gone forward enabling four officers, Inche Inus bin Molukan, Alik bin Jamin, Albert Tan and Wong Yin Fak to carry out soil surveys with a minimum of supervision. Inche Inus has done excellent work in the Beaufort - Sipitang District, the Melalap-Kemabong Plain has largely been mapped by Inche Alik and Inche Tan and Wong have done outstanding work in the Lahad Datu area.

6. One of the major problems facing these surveys in their early days was the lack of any form of topographical maps and therefore from 1955 onwards, a considerable effort has been put in by the Department on producing maps from aerial photographs using various techniques. Inche Lee Dong Yong, who started as a draughtsman in the Department, and who has subsequently received training locally and in Canada, has been largely responsible for production of most of the maps from which the soil map of the State has been drawn and on which this paper is based. He is now Head of the Cartography Division in the Research Branch of this Department.

7. In mid 1964, it was decided that, as complete map coverage of the geology of the State was available, and almost 30 percent of its area was covered by soil maps drawn on a detailed or a semidetailed reconnaissance basis, giving a thorough understanding of the type of soils to be expected from specific geological and topographical features, the time had come to put this knowledge on to a map. This map is now presented to you, not as a formal paper but for discussion in the hope that your views may assist us in resolving some of the problems of soils classification and mapping, and assessing land capabilities, this work has presented us with.

The Major Soil Groups.

I. Rock.

8. Definition. Areas covered by consolidated rock material in situ.

9. Rock Types. The principal rock types here are mainly granodioritic in composition. Rock exposures of peridotite, dunite and serpentinite also occur. Important rock areas consisting of greywacke and sandstone are seen also. Scattered localised areas of resistant limestone occur throughout the State.

10. Distribution. The largest area is located on the summit of the Kinabalu massif starting at altitudes generally between 10,000 feet and 11,000 feet. Localised areas occur on the higher ridges of the Meligan Range usually at altitudes above 4,000 feet. Also rock exposures on shear-faced limestone hills are particularly well seen at Gomantong, Tempadong, Madai and Baturong, which are all found in the East Coast Residencies.

11. Taxonomic Relationships. This unit is rarely defined as a land unit. It gains importance in Sabah because of its fairly extensive occurrence on the Kinabalu massif. Rock-land is also used as a alternative term.

12. Land Use. In the Kinabalu area this unit is reserved for recreational and scientific purposes being part of the National Park. The karst-featured hills containing caves from which edible birds nests are harvested are also State-protected and are constituted forest reserves. Limestone is quarried, for engineering purposes, from one area.

II. Lithosols.

13. Definition. Soil with a poorly developed A horizon, a thin C horizon and R at shallow depths. A high frequency of primary minerals and stones is characteristic throughout the A and C horizons.

14. Parent Material. Since these soils are essentially characterised by a state of equilibrium existing between weathering and soil forming processes, these soils are characteristic in situations where severity of the terrain is the determinative factor. They are therefore developed on a very wide range of parent rock materials ranging from dacitic lavas and pyroclastic rocks, a variety of intrusive igneous rocks consisting mainly of diorite, peridotite, dunite and serpentinite, to greywacke and sandstone.

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15. Distribution. Lithosols are found as the main soil in all steepland areas, and are particularly well-developed throughout the Western Cordillera and the Labuk, Kuamut, Segama, Bagahak, and Tawau Highlands. Lithosols also occur forming the highest ground of islands lying both in the North and also in Darvel Bay.

16. Taxonomic Relationships. The term Lithosol is commonly used in a number of soil classifications. Lithosols appear to be directly comparable to Skeletal soils in their strictest definition. The Ranker-like soils defined by Kubiena would be included here.

17. Land Use. Apart from some restricted shifting cultivation, these soils are rarely used except in the Ranau district, where almost the total production in the State of tobacco and sub-tropical vegetables is produced on these soils.

III. Rankers.

18. Definition. Soils with a fairly high humic development in the A horizon, overlying at shallow depths a C horizon. A high frequency of primary minerals and stones is characteristic throughout the profile.

19. Parent Material. These soils are developed on colluvial material, consisting mainly of sandstone, granodiorite and ultrabasic intrusive rock material.

20. Distribution. Rankers are restricted to the Kinabalu massif. Additional areas of the soil will probably be described with further work on the mountainous areas of the State. So far these soils have not been described at altitudes below 4,000 feet.

21. Taxonomic Relationships. Rankers are directly comparable to regosols developed on colluvial material. They are also closely related to skeletal soils.

22. Land Use Having a marginally wider land-use than that described for Lithosols, since in addition to shifting cultivation some market gardening and coffee cultivation at altitudes around 4,000 feet to 5,000 feet above sea level is seen on these soils. The largest extent of these soils however remains under oak forest in the Kinabalu National Park.

IV. Terra Rossa Soils.

23. Definition. Shallow soils with a A C profile. A poorly defined B horizon might be present. Characteristically red clayey and porous, these soils are developed as pockets in karst country found on resistant limestone.

24. Parent Material. These soils are developed on residual accumulations of material formed as the result of the weathering of limestones.

25. Distribution. Of extremely limited extent, these soils have so far been described at Madai, Baturong and Tempadong. They undoubtedly occur in the other limestone areas.

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26. Taxonomic Relationships. Terra Rossa Soils as described here are directly conformable to the term used by Kubiena and the Australian soil classification. Red-yellow Mediterranean Soils and Red-brown Earths have been used for loosely allied soils in other classifications.

27. Land Use. Because of their very limited occurrence as small pockets in rock areas, these soils have not been developed and remain und virgin forest.

V. Red-yellow Podzolic Soils.

28. Definition. These are soils with distinct A and B horizons. A pale A2 is characteristic marking elluviation of sesquioxides and a clearly defined B marked by sesquioxide illuviation indicated by darker, stronger or redder colours, with or without discrete iron-manganese concretions. This horizon has a wide range of colours from red to yellow. Textures are generally clayey, particularly in the B horizon, and a blocky form of structure predominates. A thickening of the A1 horizon is particularly well marked, especially at altitudes in excess of 1,000 feet.

29. Parent Material. Sandstones, mudstones and shales are the main rock material giving rise to these soils although tuffaceous sediments gain local importance particularly in the eastern half of the State.

30. Distribution. Red-yellow podzolic soils occur widespread throughout the State, but are best seen developed on the Lokan and Kaidangan Peneplains to the North-East and the Kinabatangan Lowlands and the Dent Hills to the East. Other important areas are the Milian Valley and the foot hills of the inter-montane tracts of the Western Cordillera, also the Benkoka Lowlands and Sir James Brooke Range. Three important occurrences are seen in the Tawau area, that is in the Kalabakan Valley, Sebatik Island and also on the northern part of the Semporna Lowlands. They also occur extensively on the western seaboard on the foot-hills between the coastal plain and the Crocker Range, and also on a number of outlying hills situated on the plain. Shallow red-yellow podzolic soils are to be found intermingled with the litosols throughout the montane areas, but less red colours are found in these soils increasingly with altitude.

31. Taxonomic Relationships. A very wide group of soils showing every transition into the Latosols, from which they are sometimes very difficult to distinguish. Further genetical studies are required to elucidate the relationship between these two groups of soils.

32. Land Use. These soils have a considerable land-use status. Under virgin conditions the soils normally have good stands of Dipterocarp forests and are therefore used extensively for timber exploitation. They are also used for a wide variety of agricultural purposes. Rubber is grown extensively on these soils on the West Coast and Interior, normally limited to altitudes below 1,000 feet, and also to a lesser extent on the East Coast. The development of the oil-palm industry, which is largely concentrated on the East Coast, is mainly based on Red-yellow Podzolic Soils. Coco-nut palms are grown extensively on these soils, particularly in the Kudat and Lahad Datu areas. Shifting cultivation of varying intensity is widely practised in hilly and mountainous areas, particularly in the western half of the country. Cultivation may be carried out for periods of one to three years depending on the soil fertility, and fallow periods vary from three years to nine years depending on the availability of land. The first and main crop is dry padi, with cassava as an adjunctive crop, being grown as a reserve in case of the failure of the padi This is followed usually by maize, tobacco, or cucumbers, alone or combined. Grazing for cattle is afforded by large areas of these soils in the North-West, which are degraded and where savannah conditions prevail.

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VI. Red Podzolic Soils.

33. Definition. These soils have a distinct ABC profile. Sesquioxide and clay elluviation is marked by slightly paler and slightly coarser textures in the A2., and conversely the illuviation of sesquioxides and clay is seen with a well developed B horizon, which is distinctly red and may contain ironstone concretions, and is also invariably clayey. Textures are generally clayey apart from loamy textures prevailing in the A horizon; the soil structure is invariably blocky.

34. Parent Material. Fine grained unconsolidated uplifted alluvium constitutes the parent material here. Acid extrusive rock material appears to have been the main parent rock of these alluvial deposits.

35. Distribution. Distribution is limited as a southern belt of soils associated with the volcanic peaks in the Tawau Highlands; these soils have no widespread importance in the State.

36. Taxonomic Relationships. Red Podzolic Soils in the State show close affinities to the Lateritic Red Earths of Australia and also Ferralitic Soils of Africa. They differ mainly in the low order of development of the ferro-manganese concretionary material. These soils also appear related morphologically to the Red-podzolic Soils of Australia, but differ again in one important aspect, in that the colours of the A1 and A2 horizons are distinctly redder.

37. Land-Use. These soils have been, in the past, used extensively for rubber and coconut cultivation. Small areas are also used as pepper gardens. Oil palms in recent years have been increasingly grown on these soils.

VII. Grey Podzols.

38. Definition. Soils with a very distinct ABC profile. The following horizons are diagnostic; a shallow mor O2; a pale grey sandy A2; a B marked either by illuvial iron, clay or humus, alone or combined. The soil texture and structure in the A horizon are invariably sandy and platy respectively, and clayey and blocky in the B and C horizons.

39. Parent Material. Sedimentary rocks, mainly sandstones and shales, form the parent materials of these soils at high elevations. In the low-lands these soils are formed on raised alluvial deposits, either fluviatile, lacustrine or marine in origin.

40. Distribution. Grey podzols are mainly found in the lowland areas, although they increasingly gain local importance at altitudes above 4,000 feet. In the lowland zones they cover relatively large areas particularly in the Sook and parts of the Penawan Plains and in the Tambunan, Keningau and Tenom plains occur subsidiary to, and intermingled with, latosolic soils. Very small areas also occur along all coasts.

41. Taxonomic Relationships. These are podzols sensu strictu. A prefix is used here in accordance with the terminology used for other podzolic soils named in this paper.

42. Land-Use. Various attempts have been made in the past to develop these soils agriculturally, particularly under rubber and for grazing, with absolutely no success. Silvicultural trials in the past year have established various soft wood species, largely conifers. In addition trials are being conducted to establish suitable forage crops on these soils.

VIII. Brown Podzols.

43. Definition. Soil with a deep ABC profile. The A horizon is well developed, and the B horizon generally poorly developed and marked by humus or sesquioxide illuviation. The colour of the A horizon is generally brown, but varies in darkness and strength according to a combination of age and drainage characteristics. Soil textures are essentially sandy with a single grain structure.

44. Parent Material. These soils are formed on highly siliceous stranded marine sands. Sometimes low admixtures of coralline sand occur.

45. Distribution. Occurring along the present coastline, the developmen of brown podzols is only limited by the proximity of the uplands to the sea and the deposition of active alluvium. The soils are best developed on the Crocker Plains.

46. Taxonomic Relationships. Brown podzols are essentially ground water podzols with a relatively low order of elluviation. This is manifested in the profile by the brown colours in the profile.

47. Land-Use. In the past these soils have been used extensively as pastures, but affording very poor grazing. Localised swale sites which contain open stretches of water during rainy weather have been used for wet padi cultivation, but with very little success. In very recent years, large areas of these soils have been cultivated with coco-nut palms, but the results of these efforts are far from promising.

IX. Red-yellow Latosols.

48. Definition. Soils with indistinct A and B horizons, but marked by residual concentrations of sesquioxides resulting in darker, stronger or redder colours marking a distinct horizon. This horizon has a wide range of colours, from red to yellow. A well-developed C is found. Textures are invariably clayey and a blocky structure is common.

49. Parent Material. As described for the Red-yellow Podzolic soils a wide range of similar parent materials is found with these soils. They, however, appear to be more commonly sedimentary rocks containing relatively a more basic mineral assembleage, and some cases spilitic rocks are seen to give rise to these soils. Other parent materials known to give rise to these soils are ill-assorted alluvial material, and in one important location a wide range of intrusive igneous rocks, which are mainly dioritic in composition.

50. Distribution. Sometimes intimately associated with the Red-yellow Podzolic soils, the Red-yellow Latosols occur fairly widespread throughout the State. These soils appear to gain dominance over the Red-yellow Podzolic Soils in the dryer areas of the State and in particular where soil degradation has occured and where savannah vegetation prevails. Red-yellow Latosols also occur on the westernly part of the northern seaboard of Darvel Bay.

51. Taxonomic Relationships. As described for the Red-yellow Podzolic Soils, the Red-yellow Latosols share many common characters with this latt group. As such they appear to be related to the Ferralitic Soils of Africa. Other common terms used are Red-yellow Earths, and Red-yellow Laterised Soils. It is considered that the term latosol *sensu strictu*, does not clearly apply here, but it has been used in order to bring the soil classification in line with the current terminology used in South-East Asia. The authors consider that the diagnostic colouring is due

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not so much to the accumulation of sesquioxides, whether in the hydrated form or otherwise, but to the staining of discrete mineral particles. Furthermore, it is considered that laterisation essentially involves an accumulation of sesquioxides and a depletion of silica in the appropriate soil horizons; and the soils described here are in fact probably siliceous. No evidence of the translocation of silica has so far been seen in these soils. Work is at hand to have selected profiles analysed in toto, so as to establish whether such a concentration of sesquioxides and depletion of silica is occurring, in which case these soils will be regarded as latosols. Conversely, if these analyses show that no movement of silica and sesquioxides is involved, they will be properly described as Red-yellow Earths.

52. Land-Use. These soils, as far as practical useage is concerned, have much the same range of soil characters as the Red-yellow Podzols described above. Therefore much the same pattern of land-use is seen.

X. Red-brown Latosols.

53. Definition. Being essentially a sub-group of the Red-yellow Latosols described above, these are soils with very indistinct A and B horizons. Soils profiles are essentially deep. Residual concentrations of sesquioxides are marked by slightly redder colours and occasionally by the occurrence of discrete iron-manganese concretions. Soils colours vary from red to brown in this horizon. Textures are invariably clayey throughout and a blocky soil structure is common.

54. Parent Material. Andesitic and dacitic volcanic ashes constitute the parent materials of the Red-brown Latosols. Occasionally pyroclastic boulders of very variable composition are found.

55. Distribution. In the State these soils are restricted to the Pliocene volcanic centres of the Semporna Peninsula. They are of limited extent.

56. Taxonomic Relationships. These soils have much in common with the Krasnozems of Australia. In addition they bear some resemblance to the Reddish-brown Lateritic Soils and the Eutrophic Brown Earths.

57. Land-Use. Apart from timber exploitation, the utilization of the Red-brown Latosols is limited to the cultivation of rubber only. The greatest areas of these soils, however, still remain under virgin dipterocarp forests.

XI. Red-brown Ferralsols.

58. Definition. Except for a A horizon, very indistinct horizon differentiation is seen. The soil is characterised by deep development, very high porosity due to stable crumb aggregates, and a high iron content in the fine earth fraction. A range of deep red to brown colours is found, with very little colour differentiation to depth in individual profiles. Textures are clayey, but these soils generally handle like a loam because of the unusual structure characteristics.

59. Parent Material. These soils are commonly formed on olivine basalts. Very scattered but small areas also occur derived from intrusive rocks which are ultrabasic in composition, being composed mainly of amphibolite, pyroxinite, dunite and serpentinite.

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60. Distribution. Red-brown Ferralsols occur most extensively in the basaltic areas of the Table, Quoin and Mostyn areas of the Semporna Peninsula. Smaller areas occur throughout the mountainous tracts overlying the ultrabasic rock formations in the Segama Highlands, Labuk Highlands, the Northern Islands and also some islands in Darvel Bay.

61. Taxonomic Relationships. In many features, the Red-brown Ferralsols show close affinities to the Ferrisols of Africa. An alternative name used in Sabah is Red-brown Loam. These soils are also probably related to the Dark Red and Reddish-brown Latosols used in various other systems of classification.

62. Land-Use. These soils are extensively used for oil palm, abaca and cocoa-cultivation. Ferralsols occurring on rocks of ultrabasic composition afford profound problems to agricultural development due to toxic levels and imbalances of certain major and trace elements. These problems have not been resolved and at present these soils remain under primary forest. Cocoa grown on some Ferralsols derived from basalt has also produced agronomic and nutritional problems.

XII. Ferruginous Soils.

63. Definition. Soils with a distinct ABC profile with a high concentration of ironstone, either in the form of concretions or pans, formed as the result of precipitation from ground waters highly charged with iron and manganese, and marking a distinct B horizon. The A horizon is marked by clay elluviation and loamy textures prevail. The C horizon is invariably strongly mottled and clayey. A blocky soil structure predominates.

64. Parent Material. Associated with the ultrabasic rock formations are areas consisting of basins partly or fully in-filled with colluvial material of ultrabasic composition. These basin deposits give rise to these soils.

65. Distribution. These soils are restricted to small areas lying in the Labuk and Segama Highlands.

66. Taxonomic Relationships. The Ferruginous Soils are essentially ground-water laterites. Some areas of these soils indicated on the map still require investigation. It is quite possible that well drained soils of this group occur in these areas, and this particularly applies to the Orchid Plateau. Similar soils in Africa have been called Ferrsiallitic Soils or Ferruginous Tropical Soils, and in Australia Lateritic Podzolic Soils.

67. Land-Use. These soils occur in extremely remote tracts of land and no attempt has been made to cultivate these areas. They remain therefore under primary forest.

XIII. Vertisols.

68. Definition. Soils with a ill-defined but fairly deep AC profile. The A horizon is well-structured and usually has darker colours than the C horizon. Discrete carbonate concretions sometimes occur. The clay mineralogy is dominated by montmorillonite in its primary form. These soils are essentially clayey, and the subsoil is mottled.

69. Parent Material. The parent rock material giving rise to these soils is altered tuffaceous sediments, mainly shales and mudstones, containing a very high proportion of montmorillonitic minerals. These soils are also developed on alluvial material derived from this type of rock assemblage.

70. Distribution. Vertisols are confined to parts of the Dent Peninsula, and are particularly well-developed in the Silabukan Basin. It is probably that further investigation will reveal additional areas of these soils.

71. Taxonomic Relationships. The Vertisols investigated in the State have many close similarities to the Margalitic Soils named in Indonesia. Because of their easy recognition in many other tropical countries a number of other names have been employed. For example, Gilgai Soils in parts of the Middle East, and Black Cotton Soils in Africa.

72. Distribution. Again these soils occur in remote areas and have not been subject to any extensive cultivation. These soils however have afforded very valuable timber supplies in recent years. Trial plots indicate great promise for cocoa, oil palm and coffee cultivation.

XIV. Rendzinas.

73. Definition. Soils with a well defined and fairly shallow AC profile. The A horizon is well-structured and has darker colours than the C horizon. Coralline rubble generally marks the C horizon. Montmorillonitic clays dominate, particularly in the subsoil. Clayey textures predominate throughout the profile.

74. Parent Material. The Rendzinas so far described in the State are derived from limestones which are composed mainly of coralline remains. These limestones occur as raised reef formations which are mainly Pliocene or later in age.

75. Distribution. Restricted to the eastern extremities of the Semporna and Dent Peninsulas, these soils do not have a wide distribution in the State. However, other areas probably occur on parts of the eastern seaboard which have so far not been investigated.

76. Taxonomic Relationships. The term Rendzina has an almost universal useage. In Sabah, however, Rendzinas appear to be closely related to Calcareous Brown Earths, these latter soils occurring under the more zonal conditions prevailing generally on slightly higher topographical levels.

77. Land-Use. These soils have been fairly extensively utilized for coco-nut cultivation, and also for a primitive form of shifting cultivation, particularly in the Semporna area. The main crop grown under this form of cultivation is maize together with cassava. Trial plots of cocoa, oil palms and rubber have been established in recent years on this soil, and these crops are showing considerable promise.

XV. Regosols.

78. Definition. Soils with a deep AC profile. The A horizon is poorly developed and overlies unconsolidated sands along active littoral beaches. A single-grain structure is characteristic.

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79. Parent Material. These soils being formed on active littoral beach sands show a wide range of mineralogical characters depending on the nature of the neighbouring rock formations. However, particularly on the western seaboard, these sands consist generally almost entirely of quartz grains.

80. Distribution. Regosols are restricted to sea shores throughout the State, in the form of strips rarely exceeding one hundred yards in width. The lateral distribution of these soils is only limited by estuarine deposits or rock promontories.

81. Taxonomic Relationships. As seen above the term Regosol has been used to describe, in addition to water deposited sediments, colluvial deposits. Used as such Regosols have included in its group of soils, the Rankers. In this paper Regosols are restricted to littoral soils characterised by active deposition.

82. Land-Use. These are extensively used under coco-nut palms throughout the State. Food crops are also occasionally grown, mainly ground-nuts and cucumbers or pumpkins.

XVI. Active Riverine Alluvial Soils.

83. Definition. These are soils with an indistinct ABC and deep profile. The soil forming processes are dominated by active alluvial deposition and they are generally gleyed. Sometimes an indistinct B horizon is marked by low illuviation levels of iron, clay or humus, alone or in combination. Textures and the degree of gleying vary according to the characteristic distribution of alluvial soils on a flood plain. Similarly structures vary from single grain, to platy or blocky according to the nature of the deposit.

84. Parent Material. The textures and mineralogy of these soils are mainly dependant on the nature of the parent material located in each individual catchment area. Therefore a very wide range of alluvial deposits is found.

85. Distribution. Occurring in all parts of the State, the lateral expression of these soils is dependent on the state of maturity of individual drainage systems. Hence in mountainous areas these soils are of little extent, and conversely, in deltaic regions they are widespread. The largest areas of Active Riverine Alluvial Soils are found in the valleys of the Kinabatangan and Segama Rivers, together with the deltas of these rivers, and especially the deltaic areas forming the Sugut and Bandau Plains. Smaller but important active riverine alluvial soils occur throughout the intermontane plains of the Interior and along the main Crocker Plain.

86. Taxonomic Relationships. This term includes a very wide variety of soils, and is used for the purpose of this paper to indicate soils which are periodically inundated by non-saline waters. Thus levee soils, which may be classified as Regosols are included here in addition to the other soils characteristically developed on a flood plain, for which soil such names as Hydromorphic Soils, Mineral Hydromorphic Soils, Low Humic Gley Soils and Grey Hydromorphic Soils have been variously used. The all embracing term of Alluvial Soils is also commonly employed in this context. Also included with the Active Riverine Alluvial Soils for the purpose of this paper are Padi Soils, which are characterised by a number of man-induced features such as inverted gleying, due to artificially induced but periodic flooding.

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87. Land-Use. In populated areas these soils have a very wide range of agricultural use. Very large areas, particularly on the West Coast and Interior plains support irrigated rice cultivation, which is the most important use made of these soils. Rubber cultivation in the past has been extensive, again particularly on the western plains, but the importance of these alluvial soils for rubber appears to be declining in recent years. A fairly wide variety of palms are grown, sago palms on some swampy alluvial areas, coco-nut palms on the better drained river levee area, and oil palms, in recent years, particularly on the flood plains of some of the larger East Coast rivers. Bananas are to be found on a localised scale on levee sites on some of the West Coast rivers, sometimes grown in conjunction with kapok trees. A very wide range of food crops is also grown. However, it would appear that the larger part of these soils in the State still remains under virgin forest, and affords timber resources normally varying in quantity according to drainage conditions.

XVII. Organic Soils.

88. Definition. Organic Soils have a well developed A horizon consisting of at least 30 per cent raw humus material, overlying a C horizon. They are sub-divided into high altitude peats, which are relatively shallow, and basin peats of variable thickness on the lowlands.

89. Parent Material. Remains of vegetation in various stages of decomposition essentially constitute the parent material of these soils. A wide range of such peat-forming vegetation is seen. On the high mountain areas a high proportion of moss vegetation gives rise to shallow peat deposits. In the lowland basin sites the peat deposits normally consist of tree material. Sedge peats also are sometimes found in lowland areas.

90. Distribution. Organic soils commonly occur in basin sites along the Crocker Range and are most widespread on the lowlying part of the Klias Peninsula. Areas of lesser extent occur on the major plains of the East Coast. High altitude peats are largely restricted to the Kinabalu massif.

91. Taxonomic Relationships. Organic Soils cover a wide variety of ill-drained soils for which the term Peat Soils or Muck Soils is variously used. On the State Map this name is also given to peat soils developed at very high altitudes which are comparable to High Moor Peats or Alpine Humus Soils. On the Soil Map of Africa the Organic Soils are termed Organic Hydromorphic Soils, which also include Basin Peat Soils, for which a variety of names are also used, such as Fen Soils, Bog Soils, Marsh Soils or simply Swamp Soils.

92. Land-Use. Cultivation of these soils depend on problems of accessibility at high altitudes, and also on the depth of the peat deposits on the alluvial plains. In the latter case, the nature of the mineral substratum is also a determining factor. The organic soils of the high altitudes are inaccessible for agricultural purposes and these soils remain under a typical stunted moss forest type of vegetation. However on the alluvial plains the shallower peat soils have been used for padi cultivation. In recent years, with favourable topographical conditions, artificial drainage has made available areas of these soils for agricultural purposes, mainly rubber, and increasingly in recent years for oil palms. However, due to the inherent low fertility of these soils in some localities, some minor fertility problems require resolving. Cultivation on all but the shallowest of these organic soils is generally actively discouraged.

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XVIII. Estuarine (Saline) Soils.

93. Definition. Soils with indistinct but deep AC profiles. Periodically inundated by tidal waters, these soils are gleyed and saline having total soluble salts in excess of 0.15 per cent. Textures and structures are very variable, but micropores are common particularly above the mean maximum water table. Strongly developed gleying is characteristic below this level.

94. Parent Material. As with the Active Riverine Alluvial Soils, the nature of these Estuarine Soils is essentially dependent on the composition of the rock materials forming the catchment areas of individual drainage systems. In addition, however varying proportions of alluvium of marine origin is to be found giving rise to these soils.

95. Distribution. Estuarine Soils are well developed in all delta area These soils are particularly well seen in the deltas of the Padas River the West Coast, and the contiguous deltaic plains of the Sugut and Labuk Rivers, and the Kinabatangan and Segama Rivers, all on the East Coast.

96. Taxonomic Relationships. The Estuarine (Saline) Soils have been described in other tropical countries variously as Mangrove Soils and Acid Sulphate Soils or Salt Marsh Soils.

97. Land-Use. The characteristic mangrove and nipah vegetation on these soils afford a valuable source of house building materials. Also extracts from the bark of a certain mangrove species has, up until recent years, supported a major dye industry in the State. Agricultural development on these soils has been based on some localised empoldering schemes on the West coast, and the growing of special padi varieties on some brackish areas in the Labuk Estuary.

The Soil Units Represented on the Map.

98. The soils pattern of the State of Sabah is a complex one. Even though a total of twenty-three mapping units has been established, comprising various combinations of eighteen basic soil groups, the pattern on the soil map does not really bring out the complexity of the s relationships of the country. The following are some brief notes on the main characteristics of the soil units already provisionally established with special emphasis being put on the present and future bearing of this soil pattern on the development of the State. On many of the soil survey from which the soil map of the State has been compiled it has been possible to establish and map very low categories of soils. However, during the compilation of the map it was seen that it would not be possible to include all levels of soils detail variously established, especially considering the mapping scale, which for a variety of factors was choosen to be 1:500,000., and also the degree of extrapolation which would be required for areas not investigated. Therefore on the soil map a loosely maintained level of classification is to be seen for each of the twenty-three units so defined, although each may be considered to be broadly approximate to soil association level. The main objective of this map has been to bring out as far as possible the knowledge which is available and also pertinent for the planning of agricultural development in the State. Hence each mapping element is characterised by a fairly uniform range of slope characters and the parent materials are given. In each of the soil mapping units described, the soil groups are annotated in order of importance.

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Soil Unit I. Rock, Rankers, Grey Podzols, and Organic Soils.

99. This group which covers approximately 0.42 per cent of Sabah is very imperfectly known, the information herein gained being based on a single pedological study of the South-West slope of Mount Kinabalu. The agricultural potential of this area is negligible and it now constitutes part of the Kinabalu National Park.

Soil Unit 1a. Lithosols, Rock and Grey Podzols.

100. This group is of little importance in Sabah, occupying approximately 0.89 per cent of the State. Developmental prospects are very poor being limited by steepland topography, inherently poor soil characters and also by general inaccessibility.

Soil Units 2. and 3. Lithosols, Red-yellow Latosols and Red-yellow Podzolic Soils.

101. Although of very major extent, occupying approximately 41.02 per cent of the land, and supporting at present a considerable bulk of the population, these soil units have very little prospects as far as agricultural development is concerned. This is largely governed by very unfavourable topographical characters. It has been the policy of the Government for a very long time to discourage settlement and agriculture on these soils.

Soil Unit 4. Lithosols, Red-brown Ferralsols.

102. This soil unit due to a combination of steepland topography and an unfavourable mineral nutrient status, is considered to have no potential for agriculture. It occupies approximately 4.22 per cent of the State.

Soil Unit 5. Lithosols and Red-yellow Latosols.

103. Although still almost entirely under primary forest and untouched agriculturally, these soils, again due to adverse topographical characters, are not considered suited for agricultural development. This soil unit is very susceptable to accelerated soil erosion, and has incurred severe erosional effects where timber extraction has been carried out. It occupies approximately 2.00 per cent of the State.

Soil Unit 6. Rock and Terra Rossa Soils.

104 Covering approximately 0.03 per cent of Sabah this unit is of very little importance. In addition, due to the rockiness and severity of the terrain the developmental prospects for these areas are limited to sources of rock for engineering or lime extraction purposes only. However, the present and future economic importance of the edible birds nests collected from some of these areas should not be ignored, especially since the proceeds from the sale of these nests afford almost the only source of income for some communities.

Soil Unit 7. Red-brown Latosols.

105. Supporting unduly good stands of timber, these soils, especially on the more severe slopes are probably best utilised as part of the forest estate of the country. With less severe topography, however, rubber has been developed in some areas, but anti-erosional control measures are always undertaken for development under this crop. This soil unit is again of limited extent, occupying approximately 0.29 per cent of the State.

Soil Unit 8. Red Podzolic Soils.

106. Generally developed on fairly gently sloping land, this soil unit is rapidly being utilized for agriculture, particularly in recent years. When adequately fertilized these soils support a variety of tree crops satisfactorilly. They occupy approximately 0.52 per cent of the land.

Soil Unit 9. Ferruginous Soils and Red-yellow Lateritic Soils.

107. These soils are again of very limited extent, covering approximately 0.14 per cent of the land surface. Future developmental prospects are curtailed by three important limitations, namely inferior drainage conditions and hard-pan development, alone or combined, and in some cases the steepness of the terrain. The mineral nutrient status of these soils, particularly the basin depression representatives, is good. By and large then, this soil unit holds out fair promise for successful agricultural utilization; this depending upon the selection of shallow rooting crops for the hard-pan soils and adequate amelioratory measures being resolved on drainage and topographic conditions.

Soil Units 10, 11 and 12. Red-yellow Latosols and - Red-yellow Podzolic Soils.

108. These soil units are some the most extensively by delineated, occupying approximately 36.28 per cent of the State. Although of medium fertility status only, these soils have been proven to be suited to a wide range of tree crops, depending on terrain conditions. The greatest potential source of land for development lies within this soil unit and already an oil palm research station has been established on some of its typical soil representatives. It has been found that with a number of tree crops, the rather low mineral levels of these soils are fairly easily overcome by normal applications of fertilizers.

Soil Unit 13. Red-brown Ferralsols.

109. Apart from some very small areas most of the land covered by this unit has already been alienated for agricultural purposes. An agricultural research station specializing in cocoa agronomy has been established on soils of this unit. Because of the limited extent of this soil unit, in only covering approximately 0.20 per cent of the State, and also the extent of agricultural development in the past, future developmental prospects on these soils are not great. They are, however, some of the best soils found, although some fairly acute mineral nutrient disorders are seen with cocoa growing on a particular representatives of these soils.

Soil Unit 14. Red-yellow Latosols and Grey Podzols.

110. Occupying approximately 0.54 per cent of the State and occurring in the inter-montane plains of the Interior, where there is a great deal of pressure for land for agricultural development, this soil unit has been extensively utilized in the past, and has now largely been formally alienated for this purpose. The topographical and water conditions of the soils represented in this unit are good as far as agricultural requirements are concerned. Severe nutrient deficiencies are to be seen in the Grey Podzols, and also much of the land of the Red-yellow Latosols has been subjected to severe mis-use in the past and now requires special measures to bring it back to its original fertility status.

Soil Unit 14 a. Grey Podzols and Red-yellow Latosols.

111. The soils of this unit have much the same field relationships as the latter soil unit described above, with the important exception of the predominance of Grey Podzols. In addition drainage conditions are sometimes poorer. The area covered by soils mapped in this unit represents approximately 0.75 per cent of Sabah. These soils have a very low order of potentiality as far as agricultural purposes are concerned and would possibly be best used for timber production.

Soil Unit 15. Grey Podzols and Red-yellow Podzolic Soils.

112. This soil unit occurs on rather unusual conditions in the State, occurring at altitudes between 4,500 ft. and 6,000 feet on the Pinosuk Plateau which occurs to the South of the Kinabalu massif. Occurring at this altitudinal range a variety of temperate crops could be grown, particularly on a market garden scale. In this way the poor nutrient status of these soils could be economically overcome. In recent years, however the total extent of this unit has been incorporated as part of a National Park. Approximately 0.09 per cent of the State is represented by this soil unit.

Soil Unit 16. Vertisols.

113. This unit also contains important alluvial soils, which are almost indistinguishable both morphologically and chemically from some typical representatives of such soils developed on flat lands. These alluvial soils are therefore included in this unit. By and large the Vertisols offer some of the most promising land for future agricultural development. The topography on which these soils are developed is generally very easy, and it would appear that the traditional hazard of erosion, due to alternating expansion and contraction of the montmorillonitic clays will not be severe in these soils. Indications are that the inherent clay minerals are of the poor swelling varieties. The mineral nutrient status of these soils is comparable to the highest so far determined in Sabah. Apart from a very small area, on which cocoa and oil palms have been established, the whole extent of this soil unit so remains undeveloped agriculturally. These soils comprise approximately 0.39 per cent of the State.

Soil Unit 17 Rendzinas.

114. Approximately half of the area covered by these soils supported variety of crops. In the past these soils have been mis-managed, and frequently very little soil is left. Developmental prospects of the rendzinas at present remaining under forest cover are good, particularly considering the equable terrain and drainage conditions together with fairly satisfactory nutrient levels. Rendzinas cover approximately 0.46 per cent of the State.

Soil Unit 18. Active Riverine Alluvial Soils and Organic Soils.

115. This soil unit, comprising approximately 9.08 per cent of the State, is of supreme importance to the agricultural development of Sabah. On the western sea-board plain, which supports by far the greatest concentration of settlement, almost every part of the active riverine alluvial land is used either permanently or periodically for agricultural purposes, particularly for the growing of wet padi. However, on the riverine plains of the East coast, where by far the greater extent of this soil unit occurs, very little agricultural development is seen. At present further agricultural settlement on this unit in the undeveloped areas is limited basically by a sparse population distribution, by the hazard of periodic flooding and also

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in some cases, as in parts of the Kinabatangan and Sugut Valleys by permanent swamp conditions prevailing, generally associated with which is the occurrence of peat soils. Prior to large scale development in many of these East coast valleys, comprehensive hydrological studies will be necessary to overcome these unsatisfactory drainage conditions, but it would appear that ultimately very large areas of these soils will be available for agricultural developmental purposes.

Soil 19. Organic Soils.

116. Occupying approximately 1.02 per cent of the State, these soils are of little importance to the State. However, because of the very unsatisfactory drainage conditions and the poor mechanical and nutrient medium of the deeper peats for most agricultural crops many problems require further investigation. At present it can only be said that this soil unit has very low developmental prospects as far as agriculture is concerned.

Soil Unit 20. Estuarine (Saline) Alluvium.

117. In the past, apart from growing some semi-halophytic wet padi varieties, these soils have not been utilized for agricultural development. In recent years attempts have been made to reclaim some areas of these soils by the establishment of polders. These schemes have not at present met with any measure of success, although it would appear that most of the difficulties so far encountered can be resolved with the undertaking of further amelioratory measures. By and large it would appear that the cost of reclaiming such soils at present is prohibitive, and therefore the prospects of developing these soils for agricultural purposes are poor. This soil unit covers approximately 0.96 per cent of the State.

Soil Unit 21. Regosols and Brown Podzols

118. Occurring as active sea beach deposits and also as stranded beach soils of low elevation, the soil representatives of this unit posess a variety of adverse soil characteristics as far as agricultural development is concerned. Lying at or close to the regional water table, drainage conditions, apart from the freely draining sites occupied by the Regosols, are extremely poor. Artificial drainage, which would normally be considered as an essential pre-requisite for agricultural development with such soil/water relationships, is generally difficult to undertake successfully because of the physiographic distribution of these soils close to the regional water table. In addition, the coarse soil textures result in drought conditions prevailing with prolonged dry periods. The nutrient status and mineral reserve of these soils are invariably low. Thus it can be seen that these soils, which occupy approximately 0.70 per cent of Sabah have very low value agriculturally.

The Availability of Land in Relation to Agricultural Development.

119. Throughout its history, Sabah has experienced periods when it was on the brink of a major boom, either in the form of a agricultural commodity or a mineral find. Invariably, however, most enterprises involved in such exploitation of primary products either failed or did not reach any great stage of fruition, leading one experienced but jaded commentator to describe the country as a 'land of burst hopes'. Even so, a continuously recurring theme has been the vast areas of land available for agricultural purposes, and this has always been the penultimate salve. But is this really true ? It is instructive to consider this now, with the availability of the soil map of the State, and especially with the rapid rate of agricultural development seen in recent years together with the ambitious plans currently being formulated by government for agricultural expansion.

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120. Sabah has an area of 29,388 square miles, and according to the last census taken in 1960., a population of 454, 421. This represents a total of sixteen persons to a square mile, which compares very favourably with the figure of seventy for Malaysia as a whole. There is,however, every indication that the pupulation, irrespective of immigration, is increasing by almost three per cent annually.

121. From the details contained in this paper it is possible to make a general assessment of the land as far as agricultural development is concerned. Based on this, three broad land capability classes can be recognised.

Class I. Land which is suited for a wide variety of crops, capable of giving economic returns by normal forms of husbandry, and therefore suited for agricultural development. This includes the land represented by soil mapping units numbers 7 to 14 and also numbers 16, 17 and 18.

Class II. Marginal land, which at present is not considered suited to give an economic return from agriculture, but which might in time be made productive agriculturally without a high economic investment. This class of land consist of podzols and peat soils, and is represented mainly by soil mapping units numbers 14a, 15 and 21.

Class III. Land which is largely unsuited for agricultural development, consisting mainly of mountainous land and also saline estuarine land. It would appear that this class of land would be best placed into forest reserves, being used as a source of timber produce, or protective, scenic or fauna reserves, depending on various factors.

122. From this it can be seen that approximately 47.9 per cent or 14,076 square miles is suited for agricultural development, and approximately 49.54 per cent or 14,562 square miles is unsuited for such development. A rather insignificant 2.56 per cent or 750 square miles must remain at present in an intermediate category as far as future development prospects are concerned.

123. It can be seen therefore that it is more realistic to assess the present and future density of the population, as far as agricultural development is concerned, on the extent of land suited for agriculture. This is particularly important in Sabah, whose economy is, and will increasingly be so in the forseeable future, be based on agriculture. With this in mind a far more sobering figure of 32 persons to a square mile is calculated. This figure itself can be expected to increase rapidly in the future, particularly with the improvement of government services which is to be expected, and also because of the rate of immigration which might greatly increase when the present hostilities cease. Therefore it can be seen that there is no room for any undue complacency, and it is of prime importance that the land available is used to its best capability and also cared for in order to preserve what every natural resources survey has so far indicated to be Sabah's most important long term and valuable asset, its agricultural land.

References

Cline M.G. The Soil Survey of the Territory of Hawaii. United States Department of Agriculture. (1955).

Collenette.P. The Local Deposits and Geology of the Silimpopon Area of Tawau District, Colony of N. Borneo. Mem.2. Geological Survey Department British Territories in Borneo. The Geology and Mineral Resources of the Jesselton - Kinabalu Area of N. Borneo. Mem.16. Geological Survey Department, British Territories in Borneo.(1958). Geology and Mineral Resources of the Pensiangan and Upper Kinabatangan Area of Sabah. Mem. 12. Geological Survey of the Borneo Region, Malaysia. (1965). A Physiographic Classification of N. Borneo. The Journal of Tropical Geography. Vol. 17.

D'Hoore. J.L. The Soil Map of Africa, Commission for Technical Co-operation in Africa. Pub. No. 93.

Dudal R. Moorman. F.R. Major Soils of S.E. Asia. The Journal of Tropical Geography. Vol. 18.

Fitch F.H. The Geology and Mineral Resources of Part of the Segama Valley and Darvel Bay Area of the Colony of N. Borneo. Mem.4. Geological Survey Department, British Territories in Borneo. (1955). The Geology and Mineral Resources of the Sandakan Area. Mem. 9. Geological Survey Department, British Terrotories in Borneo. (1958)

Haile. N.S. Wong. N.P.Y. Malaysia. Mem.16. Geological Survey of the Borneo Region, Malaysia. (1965).

Kirk. H.K.C. The Geology and Mineral Resources of the Semporna Peninsula, N. Borneo. Mem 14. Geological Survey Department, British Territories in Borneo (1962)

Kubiena. W.L. The Soils of Europe. (1953).

Liechti. P. Geology of Sarawak, Brunei and Western Parts of No. Borneo. Bul.3. Vols. I and II. Geological Survey Department, British Territories in Borneo. (1960).

Mohr. E.C.J. Soils of Equatorial Regions (1944).

Mohr. E.C.J. Van Baren. F.A. Tropical Soils (1954).

Panton. W.P. The 1962 Soil Map of Malaya. Journal of Tropical Geography. Vol.18. Land Capability Classification in the States of Malaya, Malaysia. Paper No.11-7. Conference on Conservation of Nature and Natural Resources in Tropical South East Asia. Bangkok. (1965).

Paton. T.R. Soils of the Semporna Peninsula. N. Borneo. Department of Technical Co-operation. Colonial Research Studies. No.36. (1961).

Reinhard. M. Wenck. E. The Geology of the Colony of N. Borneo. Bul. 1. Geological Survey Department, British Territories in Borneo. (1951).

Staff of the World Soil Resources Office, F.A.O. Preliminary Definitions, Legend and Correlation Tables for the Soil Map of the World. FAO/UNESCO Project. (1964).

Stephens. E.A. The Geology and Mineral Resources of the Kota Belud and Kudat Area of N. Borneo Mem. 5. Geological Survey Department, British Territories in Borneo. (1956).

Stephens. G.G. A manual of Australian Soils. 3rd. Edition. CSIRO. (1962).

Wilford. G.E. The Geology of Sarawak and Sabah Caves. Bul. 6. Geological Survey of the Borneo Region, Malaysia. (1965).

Wilson. R.A.M. The Geology and Mineral Resources of the Banggi Island and Sugut River Area of N. Borneo. Mem. 15. Geological Survey Department, British Territories in Borneo. (1961). The Geology and Mineral Resources of Labuan and the Padas Valley of Sabah, Malaysia. Mem. 17. Geological Survey of the Borneo Region, Malaysia. (1964).

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Wilson. R.A.M. The Geology and Mineral Resources of the Banggi Island and Sugut River Area of N. Borneo. Mem.15. Geological Survey Department, British Territories in Borneo. (1961). The Geology and Mineral Resources of Labuan and the Padas Valley of Sabah, Malaysia. Mem.17. Geological Survey of the Borneo Region, Malaysia. (1964).

DISCUSSION

Leamy: - What are the mapping units used below Great Soil Group level and what are the criteria used to seperate lower categories and the Great Soil Groups?

Thomas: - Basically, parent material, topography, age of p. material (Paton), climate also comes in to a certain extent especially in high altitudes e.g. podzolization. Below the great soil groups, family - series or sub-family - morphology of the soil profile is increasingly used as a criterion for separation.

Andriesse: - What is the maximum depth of the soil profile taken into consideration for classifying purposes?

Thomas: - A depth down to 4 ft. is generally used.

Mohinder Singh: - How important is the drainage pattern as a soil classification factor in Sabah? Can it be used as a single factor for classification at any higher level?

Thomas: - It is important as far as active riverine alluvium is concerned but it does not come directly into our classification as presented in the paper.

Andriesse: - Why separate Red Podzolics from Red-Yellow Podzolics since the latter is a combination of Red Podzolics and Yellow Podzolics suggested by Thorp and Smith because there is insufficient difference to justify separation.

Thomas: - In Sabah it is possible to separate these two groups on the basis of their parent materials but this distinction is subject to further review.

Leamy: - The split between Red Podzolics and Red-Yellow Podzolics seems to be done on strong environmental grounds, as we do in Malaya for soils on Older Alluvium. It is admitted that this distinction is based much more on the intuition of the individual surveyor than on analytical or morphological grounds.

Andriesse: - Since these Great Soil Groups have been defined elsewhere the original definitions should be adhered to and it is recommended that the term "Red-Yellow" should be used at the Great Soil Group level and a division on colour should then be made at the sub-group level.

Thomas: - We have been working with the possibility in mind of subdividing the Red-Yellow Podzolics, into 2 or 3 new great soil groups - But the main difficulty is with the soils developed on closely intercalated sandstones and shales which cover the greater part of Sabah.

A CLASSIFICATION OF SARAWAK SOILS

SOIL SURVEY STAFF

DEPARTMENT OF AGRICULTURE
SARAWAK

INTRODUCTION

The first systematic study of soils in Sarawak was made by Dames in 1955 while on attachment from F.A.O. to the Sarawak Forest Department. This work was largely confined to soils described in this classification as Podsols and Groundwater Podsols. In 1958 a soil survey organisation was established and for the first year was headed by Dames while on a second assignment attached to the Department of Agriculture. In the period 1958 - 1965 a total of 10,100 square miles were surveyed, largely by reconnaissance methods, this comprising 20.9 per cent of the State. A further 4,480 square miles were covered by terrain classification maps, based on air photograph interpretation. Survey methods have been described in the Soil Survey Division Annual Report (SARAWAK MINISTRY OF NATURAL RESOURCES, 1964, pp. 7-13).

A tentative classification of the main Sarawak soils was made by Dames (1962). Until 1964 no systematic attempts were made to improve on his work except for the preparation of the 'field classification' (ANDRIESSE, 1962) which enabled standardisation of soil association mapping units on reconnaissance soil surveys in the State. By 1965, however, sufficient data were available from a large portion of Sarawak to allow a comprehensive classification of the State's soils at a great soil group and family level to be attempted. The classification resulting from that work is described in this paper.

Table 1 : Sarawak Soil Classification - great soil groups and families

Great soil groups	Families
Skeletal soils	Meluan, Kapit, Sedong, Binatang, Kelupu, Gaya
Brown Forest soils	Kabuloh, Kedadum.
Lateritic soils	Tarat, Antayan
Red-Yellow Podsolic soils	Matang, Nyalau, Bekenu, Merit, Semilajau, Malang, Sabangang, Lupar.
Grey-White Podsolic soils	Kerait, Saratok, Lubai, Triboh
Podsols and Groundwater Podsols	Silantek, Bako, Buso, Miri, Jerijeh
Groundwater Laterite soils	Rapak, Bentang
Gley soils	Gerawat, Semadoh, Luis, Sebandi, Plan, Bijat, Gong, Embang, Matu, Tatau, Daro
Saline Gley soils	Nonok, Belat, Pendam, Rajang, Limbang
Peat soils	Igan, Mukah, Anderson, Mulu
Recent Alluvial soils	Ramun, Terbat, Sematan, Kayan, Seduau, Kabong

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The Sarawak classification is basically a genetic one. The great soil groups recognised are listed in Table 1. The concepts at this level are, in general, those of Baldwin et al. (1938) as revised by Thorp and Smith (1949). Where the range of soils within a group is altered a change in nomenclature has been made to avoid confusion. The main differences between the present classification and this earlier system are as follows:

a) Skeletal soils - are equivalent to Lithosols but include soils which Baldwin et al. would have considered shallow phases of soils in other great soil groups.

b) Lateritic soils - Reddish-Brown and Yellowish-Brown Lateritic soils are grouped together under this title. Both occur in Sarawak but colour does not appear to correlate with other characteristics.

c) Grey-White Podsolic soils - are not included in the earlier classification unless they are considered Yellow Podsolic soils but are an important group in Sarawak.

d) Podsols and Groundwater Podsols - while the concept remains unchanged, these are considered as one group as, in practice, it is difficult to distinguish between them in many localities.

e) Gley soils - are equivalent to the Low-humic Gley soils of Thorp and Smith (1949) but include some soils classed by them as Half-Bog soils. It is considered that there is little genetic justification for a group of Half-Bog soils and such soils are classed as either Gley or Peat soils, depending on the depth of the organic deposits.

f) Saline Gley soils - are included in Saline soils by Baldwin et al. but are separated here as those soils formed in a marine environment differ markedly from Saline soils formed in an arid climate.

g) Peat soils - comprise Bog soils and the majority of Half-Bog soils.

h) Recent Alluvial soils - comprise Alluvial soils and Regosols as it is considered that the latter do not require separation at this level of classification.

Classification at a family level is largely based on genetic factors, such as the origin and nature of the parent material and the degree of profile development. It is hoped that in time it will be possible to replace the present classification by that of the U.S.D.A. Soil Survey Staff (U.S.D.A., 1960) and, in anticipation of a future change, the limits of many diagnostic horizons and other soil features used in defining the families have been chosen to agree with those of the American classification.

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The main practical drawback of the Thorp and Smith classification is the lack of precise definitions. In the present classification, therefore, the concept is interpreted in terms of properties which can be seen and measured in the soil profile or can be established by simple laboratory analysis. Such an interpretation involves, in some cases, the creation of artificial limits. It is felt, however, that this classification has two major advantages. It allows consistent placement of soils at the great soil group and family levels, largely using properties which can be easily recorded in the field. In addition it is much easier to improve the classification when couched in terms of well-defined soil features than when it is limited to generalities.

In Sarawak chemical weathering proceeds to considerable depths and where deep road cutting exposures are available for study it is seen that pedogenetic processes may extend to depths of 10 or 20 feet. In soil mapping and classification, however, such deep soil horizons must be ignored as the soil surveyor's auger is generally four feet in length, although profile pits are dug to greater depths where representative profiles are required for analysis. In the Sarawak classification, therefore, the soil profile is taken to be the surface 48 inches (measured from the base of the O horizon if one is present). Only in a few cases does this lead to anomalies. There may be, for example, no profile difference other than a spodic horizon between a Podsol and a Grey-White Podsolic soil and, as the classification stands, a Podsol in which the spodic horizon, however well expressed, in not encountered within 48 inches of the surface must be classified as a Grey-White Podsolic soil. Such difficulties arise, however, wherever soil investigations rely on auger sampling. The inclusion of this limiting depth in the framework of the local classification merely recognises a situation which exists in any soil classification.

Where bisequent profiles are considered - the commonest example being thin clayey alluvial deposits overlying peats - an arbitrary depth of 20 inches is used in classifying the soil. Where the overlying material is greater than 20 inches in thickness, underlying horizons are ignored; where it is less than 20 inches in thickness, the features of the underlying material are used.

The definitions of the majority of descriptive terms and diagnostic horizons used in the great soil group and family definitions follow those of the U.S. Department of Agriculture (U.S.D.A., 1951, 1960). For ease of reference the definitions of the main terms employed are restated in the Appendix. Some general terms for texture have been defined for local use. These definitions are also given in the Appendix and the terms are marked with an asterisk where used in the text.

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SKELETAL SOILS

1. GENERAL

Skeletal soils are equivalent to the Lithosols defined by Thorp and Smith (1949, p.119), being a group of soils having an incomplete solum or no clearly expressed morphology, and consisting of a freshly or imperfectly weathered mass of hard rock or rock fragments.

Skeletal soils in Sarawak occur mainly in association with Red-Yellow Podsolic soils, principally over sedimentary and igneous rocks. The soils are predominantly young and commonly have only weak development of A horizons. They are generally stony.

2. LOCAL DEFINITION

Skeletal soils are mineral soils in which:

An R or C horizon is present within 10 inches of the base of an O horizon.

3. ENVIRONMENT

3.1. Climate. These soils are found under a 'Tropical Rainy Climate - subclass Af' (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class 1a, no month having less than 100 mm rainfall. The periodic extremely heavy rainfall is known to lead directly to the formation of Skeletal soils in places through large scale erosion.

3.2. Parent Material. The rocks over which Skeletal soils are found range from limestone to sandstone, shale and all igneous types in Sarawak. They also occur in screes and boulder fans, particularly close to igneous rock outcrops, and in old riverine alluvium. In some areas Skeletal soils are of mixed origin, for example where bedrock is overlain by a thin veneer of alluvium.

3.3. Topography. Skeletal soils are found predominantly on rugged topography with slopes exceeding 25° but the associated landforms range from lightly dissected lowlands and terraces to ridges, cuestas, karst and igneous massifs. Skeletal soils have also been found on almost flat land having an unusual geomorphic history, such as rock platforms formed by river or sea erosion and subsequently covered by a thin deposit of alluvium.

3.4. Vegetation. The primary vegetation is varied. On soils derived from igneous rocks, and to a lesser extent sedimentary rocks, it consists of Mixed Dipterocarp Forest. On the harder and more arenaceous sedimentary rocks, however, it is principally Heath Forest or, at altitudes exceeding about 3,000 feet, Moss Forest.

4. FAMILY CLASSIFICATION

The limit of 10 inches as the maximum permissible depth for Skeletal soils is chosen to represent the approximate lower limit to which the bulk of root systems normally penetrate soil. The initial separation between families is based on their origin because both the physical and chemical properties of wholly residual soils are different from those of mixed origin or those developed in coarse-textured alluvium.

A seperation of the residual soils is then made between those overlying C and those overlying R horizons. The R horizon is defined as solid bedrock, which for the purpose of field identification, is considered material too hard to auger through and which is therefore probably too hard for root penetration. The C horizon is considered weathering rock which can be augered. Two families are established with C horizons based on the total phosphorous content of the fine earth fraction. This basis for separation is tentative and is chosen to divide the relatively fertile Sedong Family soils overlying basalt and intermediate rocks, from the poorer soils of Kapit Family.

The soils of mixed origin are divided on their internal soil drainage. Texture is not considered to be sufficiently important in these shallow soils to warrant a further subdivision.

Skeletal soils formed entirely in alluvial material are classed in one family as their texture and drainage characteristics have a limited range.

Table 2: Skeletal soils - family classification

Origin of parent material	Diagnostic horizons		Family
Residual	R horizon within 10 inches of surface		MELUAN
	C horizon within 10 inches of surface	Less than 500 ppm total phosphorous in fine earth	KAPIT
		More than 500 ppm total phosphorous in fine earth	SEDONG
Mixed	Well to imperfectly drained above IIC or IIR horizon		BINATANG
	Poorly to very poorly drained above IIC or IIR horizon		KELUPU
Alluvial			GAYA

5. NOTES ON THE FAMILIES

5.1. Meluan. Soils of this family are mainly found on steeply sloping uplands underlain by sandstone and also on some karst land. They are brownish, well-drained, clays and loams and are rarely cultivated.

5.2. Kapit. Soils of the Kapit Family are widespread either singly or in association with podsolic soils throughout upland Sarawak, and in Third Division particulatly. The underlying rock is generally shale, sandstone or granite. The soils are brownish, well drained, stony, and heavy textured. They are used for hill padi in many areas.

5.3. Sedong. These soils are generally found in areas underlain by basic and intermediate rocks such as occur in parts of First, Second and Third Divisions. They are normally b ownish, well-drained, stony and heavy textured, and are commonly cultivated except where slopes are very steep.

5.4. Binatang. Soils of the Binatang Family occur in First, Third and Fourth Divisions in small valleys where thin alluvium rests on augerable shale, or on hard limestone. The soils are yellowish, well-drained and normally heavy textured.

5.5. Kelupu. This family of soils has only been seen in Third Division where it occurs in small valleys. The soils are poorly drained, heavy textured and rest on gleyed weathering shale.

5.6. Gaya. Gaya Family soils are common in parts of First, Fourth and Fifth Divisions in valley infill material, in alluvial fan deposits or on low to high terraces close to rivers which drain areas containing much sandstone. Characteristically they are poorly-sorted fragmental deposits and are rarely cultivated.

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BROWN FOREST SOILS

1. GENERAL

Brown Forest soils are rare in Sarawak and occur mainly in association with Red-Yellow Podsolic soils although in some karst areas containing igneous intrusions they are found in complex association with Lateritic soils. (WALL, et al.,1962). As in many other countries Brown Forest soils are developed over calcium-rich rocks (DUDAL and MOORMANN, 1964) and are believed to be similar to soils described by Dames (1955, pp.100-103) and to resemble some in Australia (STEPHENS, 1956, p. 30). Characteristically they are weakly developed, brownish, moderately well-drained and heavy-textured soils. Their base exchange capacity is higher than normal for residual soils in Sarawak and is dominated by calcium.

The characteristics of Brown Forest soils are summarised by Baldwin et al (1938, p.1001) as very dark brown friable surface soil grading through lighter coloured soil to parent material, little illuviation; high absorbed calcium; good drainage.

2. LOCAL DEFINITION

Brown Forest soils are mineral soils in which:

1. There is no C or R horizon present within 10 inches of the base of an O horizon,
2. the C.E.C. of the lower B horizon exceeds 20 m.e. per cent,
3. chromas are 4 or more in the B horizon,
4. there is no gley horizon within 20 inches of the base of any O horizon,
5. there is no argillic horizon.

Brown Forest soils are differentiated from Skeletal soils by the depth to C or R horizons; in places, particularly where hard limestone is beneath the soil, they may form a complex with Skeletal soils. The chemical features and the lack of an argillic horizon separate these from Red-Yellow Podsolic soils and the absence of gleying at shallow depth differentiates them from Gley soils.

3. ENVIRONMENT

3.1. Climate. These soils are found in a 'Tropical Rainy Climate - subclass Af' (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class 1a, no month having less than 100 mm rainfall. Since these soils are found in close association with Red-Yellow Podsolic soils it is considered that climate does not have an overriding influence in their development.

3.2. Parent material. The rocks found beneath Brown Forest soils have in common a high content of calcium and range from limestone and marls to calcareous shales and sandstones, intermixed in places with non-calcareous rocks. In places there is an admixture of alluvial material that has acquired a calcium-rich nature from contact with underlying limestone. The calcareous nature of the parent material is believed to be primarily responsible for the differences between these soils and the associated Red-Yellow Podsolic soils. Where the soil overlies hard limestome the soil is considered to be colluvial and not residual.

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3.3. Topography. The landforms found in areas of Brown Forest soils range from rugged karst to gently rolling hills that merge into valley land containing alluvial soils.

3.4. Vegetation. The primary vegetation consists of Mixed Dipterocarp Forest which, on areas of karst in particular, shows specialization.

4. FAMILY CLASSIFICATION

Since the Brown Forest soils have not been studied in detail the family classification is probably incomplete. In particular, it is thought that some soils of this nature may be developed partly in alluvium as well as in colluvial material.

Table 4: Brown Forest soils - family classification

Texture	Family
Heavy textured (1)*	KABULOH
Light textured (1)*	KEDADUM

5. NOTES ON THE FAMILIES

5.1. Kabuloh. The soils of this family occur in small areas in First and Fourth Divisions overlying mainly argillaceous rocks rich in calcium. Some rest on hard limestone, which in Sarawak is invariably extremely pure, and these are believed to be derived from material (mainly sedimentary in origin) that once overlay the limestone. Their calcareous nature is, in this case, an acquired feature rather than an inherited one. Similarly, other Kabuloh soils are possibly derived in part from originally non-calcareous alluvium. These soils are characterized by light yellowish brown to brownish yellow colours, heavy textures and an abrupt change from the B to C or R horizons. They tend to be dense, moderately well-drained and are commonly calcium-saturated in the deep subsoil.

5.2. Kedadum. Where sandstone lenses are interbedded with limestone, or where calcareous sandstones occur Kedadum Family soils are present. They are brownish in colour, sandy in texture and irregular in depth.

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LATERITIC SOILS

1. GENERAL

The only Lateritic soils recorded in Sarawak are similar to those described as Reddish-Brown Lateritic and Yellowish-Brown Lateritic soils in the classification scheme proposed by Thorp and Smith (1949, p.120) and which have been defined in more detail by Nyun and McCaleb (1955).

Lateritic soils are homogeneous, strongly coloured soils in which a podsol or podsolic morphology is absent. They have no albic horizon and they are usually found on parent materials rich in ferro-magnesium minerals and poor in both crystalline and compound silica.

There are recent alluvial soils derived from the same parent materials and these soils have comparable profile characteristics to Lateritic soils but are genetically distinctly different from them. It is necessary to emphasize the residual origin of Lateritic soils in the definition.

Lateritic soils are comparable in content of Group III elements and in colour to one family of the Red-Yellow Podsolic soils (the Abok Family) which can be regarded as an intergrade to Lateritic soils.

It is considered that the main factor responsible for the formation of Lateritic soils is the nature of the parent material, it being rich in ferro-magnesium minerals; under similar environmental conditions but with siliceous parent materials soils with a podsolic morphology are invariably formed.

Although clay skins are not apparent in the profile and other profile characteristics do not indicate clay leaching, clay content is nevertheless higher in the A than in the C horizon. This may be due to leaching of silica and aggregation (which decreases down the profile) of iron oxides as sand and silt particles. This small increase in clay down the profile cannot therefore be considered an argillic horizon and is not of diagnostic value.

2. LOCAL DEFINITION

Lateritic soils are mineral soils of residual origin in which:-

1. there is no C or R horizon within 10 inches of the base of an O horizon,
2. the content of Group III elements is more than 25% in the A2 and B horizons,
3. colours have chromas 4 or more in the A2 and B horizons,
4. there is no gley horizon within 20 inches of the base of an O horizon,
5. there is no hardened plinthite.

Other characteristics usually present are low levels of total silica, no mottles and a stable structure. The total phosphate content is usually higher than in any other soils found in Sarawak.

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3. ENVIRONMENT

3.1. Climate. These soils are found in a 'Tropical Rainy Climate - subclass Af' (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class 1a, no month having less than 100 mm rainfall.

3.2. Parent material.

Lateritic soils in Sarawak are derived from basic igneous rocks such as basalt, pyroxeneandesite, dolerite, and gabbro. Metamorphic rocks with closely similar chemical characteristics to this range are included. All parent materials have in common high ferro-magnesium mineral and low silica contents. The parent materials are all hard, usually non-porous and the weathering zone is thin. Spheroidal weathering is a common feature.

3.3. Topography. Lateritic soils are usually found on conspicuous hills or mountains, built of hard rock which has withstood erosion better than the usually softer sedimentary rocks surrounding them. Slopes are generally moderately steep to steep and commonly exceed 25°. The soils occur at altitudes ranging from near sea level to at least 3,000 feet.

3.4. Vegetation. The primary vegetation is Mixed Dipterocarp Forest. It is commonly characterised by a denser occurence of wild fruit tree species than on other parent materials.

4. FAMILY CLASSIFICATION

The group is represented by two families which are separated mainly on the basis of colour and structure although generally there are related chemical differences such as total iron content, base exchange and base saturation values. The differences are thought to be linked primarily with differences in lithology of the parent rocks but might also be due to differing degrees of profile development, since usually only one family is found in a given area, and a complex of the two families is rare.

Table 3: Lateritic soils - family classification

Structure	Consistency	Colour	Family
Crumb	friable	strongly brown to yellowish red	TARAT
Angular blocky	firm	olive yellow to yellowish brown	ANTAYAN

5. NOTES ON THE FAMILIES

5.1. Tarat family. Soils of this family have a fine to medium moderately developed crumb structure and are usually friable and well-drained. They are susceptible to drying out.

5.2. Antayan Family. Soils of this family have moderately developed medium to coarse blocky structures, which break down to fine or very fine blocks when dry. Colours of the Antayan soils are usually yellowish-brown rather than reddish-brown and the soils are firm when moist. Usually, fine clean quartz particles in the sand fraction can be seen in the soil. These are never seen in Tarat profiles. Chemically the Antayan soils are commonly rather richer than Tarat soils in plant nutrients and the base saturation is generally high. It is probable that, of the two, Antayan soils are the younger.

Analyses show that in both families the main clay mineral is kaolinite but a high percentage of the clay fraction is iron oxide which gives the soils a high phosphate-fixing power. "Reserve" phosphate is therefore higher than in other soils of Sarawak and is thus a useful criterion for separating them from Red-Yellow Podsolic soils.

Shallow and deep phases occur in both families. Deep phases occupy gentle upper slopes and also develop in footslope collúvium, while the shallow phases occupy moderately steep to steep hill-sides.

Both families occupy large areas of 1st Division. They are rare in 2nd and 3rd Divisions and have not been found in 4th and 5th Divisions.

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RED-YELLOW PODSOLIC SOILS

1. GENERAL

The Sarawak definition of Red-Yellow Podsolic soils follows that of Thorp and Smith (1949, p.120) but extends the possible drainage limits and interpretes other diagnostic features in terms of properties normally recorded in the field. The definition of Thorp and Smith (op. cit.) is as follows:-

'Red-Yellow Podsolic soils are a group of well-developed, well-drained acid soils having thin organic (AO) horizons over a light-coloured bleached (A2) horizon over a red, yellowish-red or yellow and more clayey (B2) horizon. Parent materials are all more or less siliceous. Coarse reticulate streaks or mottles of red, yellow, brown and light grey are characteristic of deep horizons of the Red-Yellow Podsolic soils where parent materials are thick.'

2. LOCAL DEFINITION

Red-Yellow Podsolic soils are mineral soils in which:-

1. An R or C horizon, if present, is not within 10 inches of the base of an O horizon,
2. chromas are 5 or more in the B horizon; hues are 2.5Y or redder in the B horizon; values are 5 or less in the B horizon,
3. there is no gley horizon within 20 inches of the base of an O horizon,
4. there is an A2 (possibly albic) horizon over an argillic horizon,
5. if a Bir horizon is present there is no gley horizon within 48 inches of the base of an O horizon.

Soils with a gley horizon within 20 inches of an O horizon are considered Gley soils and those with a Bir horizon overlying a gley horizon within 48 inches of an O horizon are considered Groundwater Laterite soils. Lower subsoil chromas than those given above are within the range of the otherwise similar Gley-White Podsolic soils.

3. ENVIRONMENT

3.1. Climate. These soils are found in a 'Tropical Rainy Climate - subclass Af' (KOPPEN, 1916). Where present at high altitudes they are possibly present under a cooler climate. No data are, however, available for these altitudes. The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class 1a, no month having less than 100 mm rainfall. There are no contrasts within the group which correlate with climate differences except an increase in the depth of the O horizon on the higher uplands which possibly correlates with lower night temperatures and slower organic breakdown.

3.2. Parent material. Red-Yellow Podsolic soils are predominantly developed over sedimentary rocks, ranging from coarse-grained sandstones to clay shales. Contrasts within the group commonly correlate with differences in parent material, as is discussed below. These soils have also developed in old alluvial material and to a lesser extent in recent alluvial deposits, almost at present floodplain level, on some acid igneous and siliceous metamorphic rocks.

3.3. Topography. Red-Yellow Podsolic soils are most extensive on gently rolling to strongly dissected hills but also occur on river levees and gentle undulations in river floodplains. On slopes of more than 20 - 25° soil depth is commonly limited and at least on slopes greater than 35° these soils, if they occur at all, are found in complex association with Skeletal soils.

3.4. Vegetation. The primary vegetation is almost entirely Mixed Dipterocarp Forest.

4. FAMILY CLASSIFICATION

In classifying the Red-Yellow Podsolic soils at the family level a primary division is made between those of residual origin and those of alluvial origin, as the latter commonly have higher nutrient levels.

Within the soils of residual origin two distinct but relatively minor families are first separated: those in which an albic horizon is present (developed normally over coarse-grained sandstones) and those which have more than 20 percent Group III elements in the A2 and B horizons (these being soils mainly developed over igneous rocks).

The other residual soils within the group have no albic horizon and are poor in iron. There is an obvious contrast between the rather homogenous, deep profiles with weakly expressed B horizon over some shales, and shallower heavier profiles with well-expressed B horizons over some sandstones; but no satisfactory criteria appear to be available on which the many observable permutations of profile characteristics between these extremes can be classified at the family level. Classification of these soils is made entirely on the degree of textural contrast between the A2 and B horizons. Three families have been established, approximating to light, medium and heavy textural divisions.

Within the soils of alluvial origin a subdivision is made between those on young deposits and those on old deposits; further distinction is then made between heavy-textured* and light-textured* soils within these subdivisions.

Table 4: Red-Yellow Podsolic soils - family classification

Origin of Parent material	Other diagnostic features			Family
Residual	Albic Horizon present			MATANG
	No albic horizon	More than 20 per cent Group III elements in A2 and B horizon		ABOK
		Less than 20 per cent Group III* elements in A2 and B horizons	Light-textured (2)*	NYALAU
			Medium-textured (2)*	BEKENU
			Heavy-textured (2)*	MERIT
Alluvial	Recent deposits		Light-textured (1)*	SEMILAJAU
			Heavy-textured (1)*	MALANG
	Old deposits		Light-textured (1)*	SABANGANG
			Heavy-textured (1)*	LUPAR

5. NOTES ON THE FAMILIES

Red-Yellow Podsolic soils are the most widely represented group in Sarawak. They are found in all Divisions. It is estimated that, either alone or in association with Skeletal soils, they mantle roughly 75 percent of the country.

5.1. Matang. The Matang Family is generally found over massive medium to coarse-grained sandstones in small areas of First, Fourth and Fifth Divisions. The albic horizon is commonly thin and close to the surface. The B horizon is generally a yellowish brown to reddish yellow sandy clay loam.

5.2. Abok. Abok Family soils are generally reddish yellow sandy clay loams to sandy clays. They are of local importance in First and Second Divisions, and are derived from acid igneous rocks, schists, tuffaceous sandstone and other iron-rich sedimentary rocks. Abok soils generally have low nutrient levels, the main contrast with other families in this group being the relatively high iron content.

5.3. Nyalau. The Nyalau Family is widespread in all Divisions and is developed over medium- to fine-grained sandstones or mixed sandstones and shales. Throughout the profile the soils are commonly brownish yellow sandy loams over yellowish brown to reddish yellow sandy clay loams. The soil is deep and porous. On some weakly consolidated geological formations these soils are rather unstable and liable to gully erosion. Nutrient levels are low.

5.4. Bekenu. The Bekenu Family is present, and possibly widespread, in all Divisions. It mainly comprises soils which, due to the mixed nature of the parent material, have a textural profile transitional between that of soils in the Merit and Nyalau Families. It also includes soils in which the textural contrast between the A2 and B horizons has been accentuated by colluvial processes and is not entirely attributable to vertical clay translocation. Bekenu soils have low nutrient levels.

5.5. Merit. Merit Family soils are generally yellowish brown clay loams to clays over reddish yellow clays and are widespread in all Divisions. They are derived from phyllites and fine-textured sedimentary rocks such as shales and mudstones. The B horizon is moderately well-developed although structure is commonly only weak. Shallow and moderately deep soils are most extensive. Nutrient levels are generally low, although moderately high over some geological formations.

5.6. Semilajau. The Semilajau Family is present on levees of small to medium-sized rivers, particularly where they drain sandstone hills. They are generally yellow or brownish yellow sands to sandy loams with few mottles. These soils are commonly associated with recent Alluvial and Gley soils. Nutrient levels are low.

5.7. Malang. Malang Family soils are generally yellowish brown clays present on river floodplains and are important in all Divisions. They are commonly associated with Groundwater Laterites and Gley soils. Nutrient levels are low to moderate, depending on the source of the parent material.

5.8. Sabangang. Sabangang Family soils are predominantly brownish yellow sands to sandy clay loams. Many profiles are gravelly. They have been recorded on terrace remnants in all Divisions. Unless the alluvial origin can be established by examining deep sections, as exposed in road cuttings, these soils in many instances cannot be distinguished from soils in the Nyalau Family. They are thus possibly more extensive than records indicate. Nutrient levels are low.

5.9. Lupar. Lupar Family soils have been reported on terrace remnants in Second Division. They are generally yellow to brown clays or clay loams with few mottles, commonly having a stoneline (or boulder layer) of river-worn material in the subsoil. As with the Sabangang and Nyalau Families, if no stoneline is present in the profile these soils are difficult to separate from Merit soils.

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GREY-WHITE PODSOLIC SOILS

1. GENERAL

Grey-White Podsolic soils are distinguished from the Red-Yellow Podsolic soils on account of a number of characteristics of which the near absence of iron is the most important. Connected with this feature are the generally pale colours of all horizons. Contrast between horizons is therefore weak.

The soils have strong affinities with the 'Bleached Soils' of Indonesia described by Dames (1955, pp. 91-94).

The Grey-White Podsolic soils are soils in which podsolic features such as an argillic horizon and the formation of weak to strongly developed albic horizons are conspicuous. They, however, never show development of a spodic horizon.

The group appears to be an intergrade between Red-Yellow Podsolic soils, which also have an argillic horizon, and/or a weak albic horizon, and Podsols which display in Sarawak the same pale colours but have a weak or strongly developed spodic horizon. The available evidence suggests that Grey-White Podsolic soils were formed by some of the environmental conditions under which the Podsols are formed; but other factors, such as texture and slope, prevent the strong leaching and accumulation of humic materials in a definite horizon. Soils which could be classified as immature or weak Podsols are by definition excluded from this group.

At present some soils within the group occur in association with Podsols and are sandy. The environment is favourable for the development of the true Podsol profile in time and, although such soils are very difficult to separate from the Grey-White Podsolic soils, they are best placed in the Podsols on account of genetic factors. In practise they are difficult to separate in some localities and this underlines the weakness of a genetic classification system in which the genetic processes frequently have to be deduced from environmental factors.

The Grey-White Podsolic soils are not included in the scheme proposed by Thorp and Smith (1949).

2. LOCAL DEFINITION

Grey-White Podsolic soils are mineral soils in which:-

1. an R or C horizon, if present, is not within 10 inches of the base of an O horizon,
2. there is an argillic horizon,
3. there is no gley horizon within 20 inches of the base of an O horizon,
4. there is no spodic horizon,
5. chromas are 3 or less in the A2 horizon, 4 or less in the B horizon; hues are more yellow than 2.5Y in the A2 and B horizons; values are 6 or more in the A2 and B horizons.

3. ENVIRONMENT

3.1. Climate These soils are found in a 'Tropical Rainy Climate - subclass Af' (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954) is Class 1a, no month having less than 100 mm rainfall.

3.2. Parent material. The parent materials are almost without exception quartzose and poor in ferro-magnesium minerals. Where consolidated rock forms the parent material it consists mainly of carbonaceous shales, sandy shales, shales rich in vein quartz and some sandstones. Where the parent material is unconsolidated it is invariably colluvium or old alluvium.

3.3. Topography. The Grey-White Podsolic soils have been found mainly on low hilly terrain comprising dissected terraces and strongly dissected erosion surfaces.

3.4. Vegetation. This ranges from Mixed Dipterocarp Forest to Heath Forest, the latter generally being indicative of the more sandy soils in the group.

4. FAMILY CLASSIFICATION

The group is subdivided into four families, the separation of which is based on differences of parent material and texture.

Table 5: Grey-White Podsolic soils - family classification

Origin of parent material	Texture of B horizon	Family
Residual	fine*	KERAIT
	coarser than fine	SARATOK
Old alluvial	fine*	LUBAI
	coarser than fine*	TRIBOH

5. NOTES ON THE FAMILIES

5.1. Kerait. The Kerait Family is typically found on Triassic carbonaceous shales in First Division. The soils commonly occur in complex association with Red-Yellow Podsolic soils.

The soil is usually dark grey at the surface becoming increasingly pale with depth. In most profiles the total iron content is too small to show a colour difference between A2 and B horizon although pale yellow mottles may occur in the latter. The B horizon is therefore mainly characterised by an increase in clay content. Structure in the B horizon is usually coarse blocky, and during dry periods large cracks spread from the A1 horizon to the deep subsoil allowing surface humic material to leach down. Removal of clay from the A horizon and its accumulation in the B horizon is indicated by thick clay skins lining the cracks.

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The texture is mainly sandy loam to sandy clay loam grading into clays in the B horizon. The soils are generally deep, commonly exceeding 10 feet. In road cuttings, a distinct change from the white soil material to the black weathered carbonaceous shale can be seen. The soils are moderately well drained in the A horizon but drainage is impeded in the lower horizons and water movement is largely confined to the large cracks formed during dry periods. The steep slopes usually enhance rapid run off.

Some soils in this family have distinct reddish mottling in the B horizon but the matrix colour of the whole profile remains white to pale yellow. These soils may be intergrades between Grey-White Podsolic soils and the more strongly coloured Red-Yellow Podsolic soils.

All soils in this family have low nutrient levels. The clays are mainly pure fireclays with few impurities.

5.2. Saratok. Soils of this family usually occur on carbonaceous sandstone, quartzitic sandstone and colluvial material derived from such parent rocks. They are mainly found in First, Second and Third Divisions.

Colours, although pale throughout, are normally somewhat stronger than those of the Kerait Family. Structure is commonly blocky in the B horizon and the consistency is friable in the A horizon but firm in the B. The soils are predominantly quartzose. An albic horizon is usually present but only apparent where the B horizon is pale yellow. Textures vary from sandy loam in the topsoil to sandy clay loam in the B horizon. Usually the silt fraction comprises a high proportion of the fine earth. The clay fraction is essentially kaolinitic but is believed to be partly pure silica. Where the soils are developed in colluvial material, quartz stonelines are normally found at different depths in the profile. Although the texture change from the A2 horizon to the B horizon is normally gradual, in certain bisequent soils it is abrupt. If this change occurs within a depth of 20 inches, and the underlying material is not typical of a Grey-White Podsolic profile, then the soil is classified according to the nature of the underlying material. Bisequent profiles commonly occur in colluvial material especially where outwash material from terraces overlies recent alluvium.

Chemically all soils in this family are poor. The A2 horizon in particular has a low exchange capacity and high pH values.

5.3. Lubai. Little information on Lubai soils is available since old alluvium of a clayey nature is not usually found in Sarawak. They have only been mapped in Lundu District, First Division where they occupy extensive marine terraces.

The carbonaceous shales on which Kerait soils have formed were originally deposited in a brackish water environment and the source material was poor in iron. One cannot therefore expect to find much difference between Lubai and Kerait soils and this presents difficulties in mapping them where they occur in association.

5.4. Triboh. Triboh soils are widespread in First Division and to a lesser extent in Second, Third and Fourth Divisions. They have so far not been found in Fifth Division.

Triboh soils are quartzose in nature and the texture contrast between layers in the profile may be great. Gravelly layers may alternate with clayey ones. Triboh soils are coarse-textured, chemically poor and are expensive to farm. These soils are only intensively used around Kuching where, through incorporation of much organic material such as dung, vegetable production is economically possible.

PODSOLS AND GROUNDWATER PODSOLS

1. GENERAL

The soils in Sarawak having a podsol morphology, with few exceptions contain a perched watertable within or on the spodic horizon. It is by no means clear, however, if all such soils have formed because of the presence of this watertable, although it is improbable that those found at the existing regional groundwater level can have been formed in any other way. Because there is still some doubt as to their origin, this section is given the heading of Podsols and Groundwater Podsols. For convenience they are all termed Podsols below unless a specific reference is made to the Groundwater Podsols.

All these soils are so highly siliceous and low in sesquioxides that humus is virtually the only constituent leached from the A to the B horizons. They have been described as Humus Podsols by Dames (1962, p.65). Some profiles, however, have iron compounds as the dominant B horizon accumulation. Podsols are described by Baldwin et al (1938, p.997) as consisting of a few inches of leaf mat and acid humus, a very thin dark gray A1 horizon, a whitish gray A2 a few inches thick, a dark or coffee brown B1 horizon and a yellowish brown B2 horizon. They are strongly acid and well drained.

The Groundwater Podsols are described (op. cit, p.1000) as having an organic mat over very thin acid humus, over a whitish-gray leached layer up to 2 or 3 feet thick, over brown or very dark-brown cemented hard pan or ortstein. They are imperfectly to poorly drained.

In Sarawak, soils with a podsol morphology characteristically have a thick O horizon, a thin to thick A1, and thick A2 horizon over a soft to hard Bh horizon. They cannot be classified satisfactorily into either of the two groups defined above.

2. LOCAL DEFINITION

Podsols and Groundwater Podsols are mineral soils in which:-

1. an R or C horizon is not within 10 inches of the base of an O horizon,
2. there is an albic horizon,
3. there is a spodic horizon,
4. groundwater is periodically present in at least the A2 or B horizons.

The presence of a spodic horizon differentiates these soils from all other groups except some Skeletal soils which have this feature within 10 inches of the base of an O horizon. Where gleying occurs close to the surface, which feature would otherwise qualify the soils for Gley soils, the presence of a spodic horizon is taken to be of greater importance; thus all drainage classes may occur in this group.

3. ENVIRONMENT

3.1. Climate. These soils are found under a 'Tropical Rainy Climate - subclass Af' (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class 1a, no month having less than 100 mm rainfall, Since Podsols occur in close association with Red-Yellow Podsolic and other soils, the importance of climate in their development is considered less than that of parent material.

3.2. Parent material. The parent materials of Podsols are characteristically strongly siliceous and extremely low in weatherable minerals. They range from arenaceous sedimentary rocks of Permian to late Tertiary age, to Pleistocene and Holocene coarse sediments; admixtures of more argillaceous material occur in places.

3.3. Topography. The associated landforms are beaches, terraces, cuesta dip slopes, plateaux and rugged montane areas. The topography is characterized by gentle to moderately steep slopes even in the highland areas.

3.4. Vegetation. The primary vegetation is generally Heath Forest in the lowlands (WOOD and BECKETT, 1961, p.226), but Moss Forest at altitudes exceeding about 4,000 feet. Both tend to be dominated by pole-like trees of a sclerophyllous nature; needle-leaved trees are common.

4. FAMILY CLASSIFICATION

The initial division at family level is based on whether the soils are residual or alluvial in origin. Where the C horizon cannot be examined this difference is in places difficult to establish from morphological evidence alone but taking into account the site properties of a profile there is normally little difficulty in their differentiation. Thus Bako and Silantek soils are derived from thick-bedded, gently dipping sandstone giving ridge-like to plateau and cuesta topography, while the other families occur solely on terraces, alluvial fans and beach deposits.

The next criterion for family separation is whether the spodic horizon is predominantly one of humus, or of iron accumulation. Only the Jerijeh Family has a Bir horizon, which is reddish brown, mottled with paler colours. Soft iron concretions are common in some Jerijeh soils. All the other families have dark-coloured Bh horizons.

The families are then differentiated by the degree of development of the spodic horizon. In the field a strong spodic horizon is taken to be one which cannot be augered through easily. The strong spodic horizons of the Miri and Bako families are thought to be due to periodic drying of the profile which causes cementation of the sand grains. Despite being extremely hard to penetrate by spade or auger, however, broken-off fragments of this horizon are crushable between the fingers and on air-drying disintergrate to single-grain, humus-coated sand. A weak spodic horizon is one which can be augered through without difficulty and is essentially friable. The weak Bh horizon of the Buso Family is thought to be due to permanent waterlogging in the zone of the groundwater table in, for example, beachsand; that of the Silantek Family is suspected to be associated with slightly more clay in the subsoil.

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Table 6: Podsols and Groundwater Podsols - family classification

Origin of parent material	Type of spodic horizon		Family
Residual	Bh	Weak	SILANTEK
		Strong	BAKO
Alluvial		Weak	BUSO
		Strong	MIRI
	Bir	Weak	JERIJEH

5. NOTES ON THE FAMILIES

5.1. Silantek. Soils of this family are derived from arenaceous sedimentary rocks and are found on gentle to moderately steep slopes. Under primary forest they have a thick well-rooted O horizon and a distinct A1 horizon. The A2 horizon is a light-coloured sandy loam to sandy clay loam which overlies a heavier-textured Bh horizon. This consists of pale-coloured sandy clay loam to sandy clay prominently mottled with dark brown humus. The soil beneath is commonly weakly permeable and clayey. The soils are very siliceous, acid and highly leached of bases and soluble mineral nutrients. Structural faces and root channels are favoured sites for humus accumulation.

5.2. Bako. Soils of the Bako Family are found mainly on gentle to moderately steep slopes. Like Silantek soils, they are derived from arenaceous sedimentary rocks. Under primary forest the O horizon is thick and well-rooted and beneath the well-developed A1 horizon is light grey, loose sand. This sand rests abruptly on a dark-brown hard humus pan which overlies rock or more clayey material. The humus pan is always continuous.

5.3. Buso. Buso Family soils mainly occupy flat or gently sloping terraces, bouldery and sandy-textured colluvial fans and some beach deposits. Typically they have moderately thick, well-rooted O horizons and a distinct A1 horizon. The A2 horizon is pale-coloured sand to sandy loam which overlies a soft, continuous or intermittent Bh horizon. The C or IIC horizon beneath is commonly more clayey and may contain gravel and boulders, particularly in the alluvial fans. Those soils developed in beach sand have a permanently high water table, whereas the terrace and colluvial soils dry out periodically.

5.4. Miri. Soils of the Miri Family are found almost entirely on marine terraces. They have a thick, well-rooted O horizon and a distinct A1 horizon which gives way to white, loose, single grain sand, in some locations cemented at the base, that changes abruptly to a hard, dark brown or black humus pan, commonly holding up a perched water table. In some places the pan rests on a relatively unweathered wave-cut rock platform. In other cases the IIC horizon is comprised of impermeable clayey sediments. The original freely permeable nature of the sand is thought to have allowed free movement of humus-containing soil water.

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5.5. <u>Jerijeh.</u> Soils of this family are confined to small coastal areas, notably in First Division where basic igneous rocks occur close to the coast. They consist of well-drained sands with a water table periodically rising to about 24 inches. The A2 horizon is irregular in thickness, grey to pale yellow in colour, and changes rapidly to a strong brown B horizon with a concentration of soft iron concretions in its upper part. In the zone of the fluctuating water table the strong brown matrix colour is coarsely mottled yellow and within the permanently waterlogged zone grey colours are dominant.

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GROUNDWATER LATERITE SOILS

1. GENERAL

Groundwater Laterite soils are not defined by Thorp and Smith (1949) and for Sarawak a local concept has had to be adopted to separate these soils from other Groups.

Groundwater Laterite soils occupy small areas and seem to be confined to two distinctly different situations. Firstly, they occur in association with iron-rich soils such as Lateritic soils and some families of the Recent Alluvial soils where intermittent groundwater levels formed iron concretions or cemented iron pans. They also occupy small areas of old erosion surfaces where groundwater is now absent. It is believed that the latter are fossil soils.

All the soils have in common an iron-rich layer which has hardened or may harden on drying out. This material qualifies for plinthite. It has not been possible to distinguish between iron-rich, mottled layers which harden on drying and those which do not. Therefore only the hardened type of plinthite is considered to be diagnostic of Groundwater Laterites.

2. LOCAL DEFINITION

Groundwater Laterite soils are mineral soils in which:-

1. there is hardened plinthite but not within 10 inches of the base of an O horizon,
2. there is no albic horizon.

3. ENVIRONMENT

3.1. <u>Climate</u>. Groundwater Laterite soils are found in a 'Tropical Rainy Climate - subclass Af' (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class 1a, no month having less than 100 mm rainfall.

3.2. Parent material. These soils have a wide range of parent materials but are most commonly developed on materials rich in ferro-magnesium minerals, such as basic igneous rocks.

3.3. Topography. Where fossil soils occur the associated landforms range from comparatively undissected terraces to strongly dissected erosion surfaces. In the latter Groundwater Laterite soils are commonly confined to the summits of hills but even on such sites they are only patchily present. On the terraces these soils are normally more extensive. Groundwater Laterite soils are also found on footslopes in association with Lateritic soils.

3.4. Vegetation. In all areas mapped the primary vegetation has been removed. The secondary growth is usually stunted and contains Heath Forest species.

4. FAMILY CLASSIFICATION

Until more information on these soils is available the only distinction made is between soils of upland localities and those at present floodplain level.

Table 7: Groundwater Laterite soils - family classification

Site	Family
Upland	RAPAK
Floodplain	BENTANG

5. NOTES ON THE FAMILIES

Normally the families occur in small areas which are only possible to map by detalied surveys. Since little information is available no attempt is made to discuss these families further.

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GLEY SOILS

1. GENERAL.

Gley soils are comparable to the group of Low-humic Gley soils defined by Thorp and Smith (1949, p.119) and to the Grey Hydromorphic soils defined by Cline (1955, p.84). Both definitions however, exclude gleyed soils with thin surface peat accumulation. Baldwin et al (1938, p.1000) classed these as Half Bog soils. Where this accumulation is less than 10 inches thick it is considered that such soils are probably best classed with the other gleyed soils. In Sarawak a group of Gley soils has therefore been locally defined.

The majority of Gley soils are easily recognised but in some places they are difficult to distinguish from Saline Gley soils, which may differ only in the salinity of the groundwater as measured by its conductivity. Also, soils on upland sites, where the profile is low in iron and gleying has minimal expression, have many similarities to profiles of Grey-White Podsolic soils. The difficulty of classifying soils in which both mineral and organic layers are found is discussed under Peat soils.

The local definition, given below, is thus not entirely satisfactory for delimiting some soils within the group.

2. LOCAL DEFINITION

Gley soils are mineral soils in which:-

1. an R or C horizon is not within 10 inches of the base of an O horizon,
2. any peaty O horizon is not more than 10 inches in thickness,
3. a gley horizon is present within 20 inches of the base of an O horizon,
4. Groundwater conductivity does not exceed 500 micromhos per cm at 25°C at any time of year,
5. there is no spodic horizon,
6. there is no hardened plinthite.

Groundwater conductivities higher than those stated above qualify for the group of Saline Gley soils. The presence of a peaty O horizon deeper than 10 inches indicates a Bog soil. A spodic horizon is diagnostic for Podzols.

3. ENVIRONMENT

3.1. Climate. Gley soils are found in a 'Tropical Rainy Climate - subclass Af' (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class 1a, no month having less than 100 mm rainfall. No contrasts within the group correlate with climatic differences.

3.2. Parent material. Gley soils are developed largely in marine and riverine clays and to a minor extent in riverine sands. Semadoh and Gerawat Families are developed over shales, and possibly mixed shales and sandstones.

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3.3. Topography. These soils are found on flat or gently undulating valley bottoms and old beaches, on low hills and on long gentle dip slopes. Topography is probably the most important environmental factor in the development of these soils. Except where developed in heavy parent material, they are associated entirely with areas of slow external drainage.

3.4. Vegetation. The upland residual soils (Semadoh and Gerawat Families) are found under Mixed Dipterocarp Forest or, where recorded at high altitudes, under Moss Forest. The soils derived from recent riverine material bear a cover of Freshwater Swamp or Riparian Forest in the few areas where they have not been cleared for cultivation. Soils from old riverine material are generally found under Heath Forest and those from marine alluvium under Littoral or Swamp Forest.

4. FAMILY CLASSIFICATION

Classification at a family level is based on the origin of the parent material, the presence or absence of a thin peaty O horizon, and the texture of the subsoil. The classification is given in tabular form below.

Table 8: Gley soils - family classification

Origin of Parent material	Peaty O horizon less than 10 inches thick	Texture	Family
Residual	present	heavy (1)*	GERAWAT
	absent	heavy (1)*	SEMADOH
Recent riverine	present	light (1)*	LUIS
		heavy (1)*	SEBANDI
	absent	light (1)*	PLAN
		heavy (1)*	BIJAT
Old riverine	absent	light (1)*	GONG
		heavy (1)*	EMBANG
Recent marine	present	light (1)*	MATU
	absent	light (1)*	TATAU
		heavy (1)*	DARO

As can be seen from Table 8, certain combinations of the features used for family classification have not yet been recorded and possibly do not occur.

5. NOTES ON THE FAMILIES

5.1. Gerawat. Gerawat Family soils have only been noted in small areas in Fourth and Fifth Divisions and probably have a very limited distribution. They are found on long gentle slopes where they consist of a shallow, gleyed sandy clay soil overlain by thin, rather mossy peat. Other locations include the ridges of mountains within the Moss Forest zone above 4,000 feet where Peat soils are also found.

Here the soil depth is varied as rock outcrops are common. Gerawat soils are commonly found in association with soils of the Semadoh Family.

5.2. Semadoh. These soils have been recorded in Third, Fourth and Fifth Divisions and are probably present throughout the country although, where they have been seen, they do not cover wide areas and are unlikely to be widespread in any locality. They are grey, mottled, heavy-textured hill soils, the gleyed nature of which is attributed to an impervious subsoil or substratum and/or to gentle gradients and slow surface run-off. These **soils are of** little agricultural importance.

5.3. Luis. These soils commonly occur as small areas and are usually found with sandy riverine soils of the Plan Family. The most common locations are in headwaters of rivers draining areas with sandy residual soils. The soils are very poorly drained. The mineral soil beneath the surface peat or muck is pale to dark coloured, light-textured and commonly poorly sorted.

5.4. Sebandi. Soils of this family are present in all parts of lowland Sarawak where they occupy a band in riverine floodplains between other Gley soils and Peat soils. The soils consist of pale-coloured, plastic, heavy-textured material overlain by a thin peaty topsoil. The fertility is variable and crops grown range from swamp padi to coconuts, sago and rubber.

5.5. Plan. Plan Family soils are present throughout the country but rarely cover extensive areas. They are commonly recorded in small valleys, particularly where rivers drain uplands mantled by coarse-textured residual soils. They are generally grey in colour, sandy and poorly sorted. These soils are of only local agricultural importance.

5.6. Bijat. Bijat soils are generally light grey mottled clays. They are widespread soils on the bottomlands throughout the country, except where Peat soils are developed. Much of the wet padi in the country is planted on Bijat soils, which are also used for rubber, coconuts and other crops.

5.7. Gong. Soils of this family are generally light grey sands or coarse sandy loams. They are of local importance in First Division and possibly elsewhere. They occur on low-level terraces or, where associated with underlying limestone, may be at present floodplain level. They are rarely used for agriculture.

5.8. Embang. These soils, like Gong Family soils, have only been mapped in First Division. They are generally grey to light grey clays or sandy clays. They are commonly found at present floodplain level and are used in places for wet land crops.

5.9. Matu. These soils only occur in coastal areas. They occupy wide belts on swamp margins, notably in Third and Fourth Divisions, and long narrow swales between higher coastal beachlines. The subsoil has low chromas, is light-textured, well-sorted and of low fertility. The peaty topsoil has a higher nutrient status than the subsoil although it is acid and poorly decomposed. Coconuts are grown on the soils in some localities, and in Third Division the soils support coarse grasses for grazing.

5.10. Tatau. These soils are common near the Third and Fourth Division coasts east of Tanjong Jol. In Second Division they are only important between Kabong and Grigat and in First Division west of Tanjong Po. They are not common along the Fifth Division coast. These grey, poorly-drained sandy soils are commonly used for coconuts and vegetables.

5.11. Daro. Daro soils are reclaimed Saline Gley soils which, through leaching and drainage, have groundwater conductivity levels too low to qualify for grouping in the Saline Gley soils. They are generally grey clays with few mottles. They have been recorded in Third Division near Matu and are probably present elsewhere.

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SALINE GLEY SOILS

1. GENERAL

Saline Gley soils are only represented in Sarawak by hydromor[illegible] soils developed in areas subject to incursions by sea-water and th[illegible] have medium to high levels of salts in the groundwater. They are included in the Saline soils of Baldwin et al (1938, p.994). In the absence of a standard definition, the limits of this group have been defined locally.

As Saline Gley soils in this classification are considered to be only those which are now saline, soils formed in a marine environment but which occur in areas reclaimed by drainage and have been leached of salts are excluded from the group.

Strongly saline conditions are normally indicated in the field by halophytic vegetation. Weakly saline conditions are less easy to recognise and the soils may have no physical characteristics which obviously contrast with those of non-saline Gley soils. Classification has, therefore, to rely on conductivity measurements of the groundwater, a more detailed study of salinity being normally impracticable under field conditions. It is possible to use conductivity in classifying these soils as, in Sarawak, 'fresh' river water has a conductivity of less than 100 micromhos except in streams draining areas of linestone. A lower limit of 500 micromhos (per cm at 25°C) is therefore used to separate Saline Gley soils from other soils.

This system requires improvement and two major criticisms can be made. Firstly, the lower limit of 500 micromhos is only a compromise as (a) it is too high to separate fresh from brackish water and (b) it is too low to have much practical significance for agriculture. On present evidence it appears that salinity only becomes a farming problem in connection with most crops above a level of 1,000 or 1,500 micromhos. Secondly, the conductivity of the soil groundwater varies widely, being influenced by the tide, the degree of fresh-water flooding and rainfall. While one high reading always indicates a saline soil by this definition, one low reading does not necessarily indicate a non-saline soil.

2. LOCAL DEFINITION

Saline Gley soils are mineral soils in which:-

1. An R or C horizon is not within 10 inches of the base of an O horizon,
2. groundwater conductivity exceeds 500 micromhos per cm at 25°C at some time of the year,
3. a gley horizon occurs within 20 inches of the base of an O horizon.

3. ENVIRONMENT

3.1. Climate. Saline Gley soils are found in a 'Tropical Rainy Climate - subclass Af' (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class 1a, no month having less than 100 mm rainfall.

3.2. Parent material. Saline Gley soils are developed in alluvial or organic deposits. While such soils are present in coastal sands those developed in alluvial clays are much more widespread.

3.3. Topography. These soils develop on flat terrain situated between low tide and high tide levels. Complex creek patterns and numerous mud lobster mounds commonly give a strongly developed micro-relief.

3.4. Vegetation. While there is no exact correlation between degree of salinity and natural vegetation, mangrove, *Nypa fruticans* and *Oncosperma filamentosa* are useful indicator species which, in the order given, generally reflect decreasing salinity levels.

4. FAMILY CLASSIFICATION

Within the group of Saline Gley soils a division i first made between mineral and organic soils. The organic soils are not subdivided further. The mineral soils are subdivided into two texture groups and these are further divided into weakly saline and strongly saline groups. The family classification is given in tabular form below.

Table 9: Saline Gley soils - family classification

Parent material	Texture of mineral soil	Salinity	Family
Mineral	Light-textured (2)*	weakly saline	NONOK
		strongly saline	BELAT
	Heavy-textured (2)*	weakly saline	PENDAM
		strongly saline	RAJANG
Organic			LIMBANG

The mineral soils, when reclaimed and leached of salts, are considered Gley soils (see Tatau and Daro families).

5. NOTES ON THE FAMILIES

5.1. Nonok. Nonok Family soils are grey sandy loams developed on swales formed by old beach deposits and on coastal flats.

5.2. Belat. Belat Family soils are generally grey sandy loams to gravelly sands. They are developed in colluvial wash from nearby marine or riverine terrace deposits and are also found on sandspits below high tide level.

5.3. Pendam. Soils in the Pendam Family are generally greenish grey to dark grey clays, commonly found bordering estuaries although occurring in other coastal situations. Characteristics are varied, as Pendam soils are commonly thoroughly mined by the mud lobster (*Thallassima anomala*) In many areas these soils have been cultivated for wet padi or coconuts and their saline character is only apparent in groundwater analyses.

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5.4. Rajang. Rajang Family soils are dark grey to greenish grey cl which, in most areas, have been left in their natural state, have been mined by mud lobsters to give numerous mounds and hummocks an are crossed by a close pattern of tidal creeks. The primary vegeta is mangrove and *Nypa fruticans*.

5.5. Limbang. Limbang soils comprise fine woody debris, largely derived from mangrove and *Nypa fruticans*, or from the debris of Freshwater Swamp Forest tree species.

Saline Gley soils are found throughout the coastal areas of Sarawak although along much of the coast they form only a very narrow and commonly broken belt. They are widespread in the coasta reaches of the Kayan, Sarawak and Sadong Rivers, First Division, in the delta of the Rajang River, Third Division, and around Brunei Bay in Fifth Division.

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PEAT SOILS

1. GENERAL

Peat soils are largely equivalent to the Bog soils of Baldwin et al (1938, p.1000), and are widespread throughout lowland Sarawak and in some mountainous areas, covering about 13 per cent of the State. They normally occur in association with Gley soils. Peat soils are permanently waterlogged and consists of raw, generally woody peat exceeding 10 inches in depth and rest on gleyed mineral soil. In places, particularly close to large, meandering rivers, soils occur which consist of deposition sequences of mineral and organic material in lenses or bands. Where the surface organic horizon does not exceed 10 inches and the underlying soil consists of depositional layers of mineral and organic material, the depositional organic layers together must exceed 65 per cent of the profile beneath the O horizon. Where these organic layers comprise less than 65 per cent the soil is classed as a Gley soil, not a Peat soil.

Baldwin et al (op. cit) described Bog soils as brown, dark brown or black peat or muck over brown peaty material, with very poor internal drainage. The local definition of Peat soils follows this concept but specifies a minimum depth of 10 inches, shallower organic soils being grouped in the Gley soils.

2. LOCAL DEFINITION

Peat soils are organic soils in which:-

1. The O horizon consists of peat or muck (more than 35 per cent organic matter) and is more than 10 inches deep,
2. groundwater conductivity does not exceed 500 micromhos per cm at 25°C. at any time of year.

3. ENVIRONMENT

3.1. Climate. Peat soils are found in a 'Tropical Rainy Climate - subclass Af' (KOPPEN, 1916). Where present at high altitudes, they are possibly present in a cooler climate. No data are, however, available for these areas. The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class la, no month having less than 100 mm rainfall. In the lowlands, climate does not appear to be a major factor in the development of Peat soils, but at altitudes exceeding about 4,000 feet the cooler temperatures, persistent cloudiness and high rainfall are probably the prime reason for the existence of these soils.

3.2. Parent material. Peat soils consist of deep organic accumulations of Freshwater Swamp Forest and Moss Forest debris, although the basal peat of the lowlands is commonly formed of Saltwater Forest remnants (ANDERSON, 1964, p.13). The organic accumulation overlies gleyed mineral material. The organic deposits range in composition from well preserved wood, leaves and grass to comminuted plant remains.

3.3. Topography. Peat soils occur largely in alluvial basins. Where best developed, these topogenic Peat soils have a domed surface, steepest at the margins, the highest point of which is, in some places, 60 feet above river level. Climatogenic Peat soils are and found at altitudes of about 4,000 feet where in some areas they form a more or less continuous mantle over all but the steepest slopes.

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3.4. Vegetation. The primary vegetation on Peat soils is Peat Swamp Forest on lowland peat (ANDERSON, 1963, pp.142-144) and Moss Forest at high altitudes.

4. FAMILY CLASSIFICATION

The initial subdivision at family level is based on topograph A secondary subdivision is then made on the depth of the peat, an arbitrary limit of 40 inches being considered of agricultural significance. The shallow peats are then separated on the basis of the texture of the mineral subsoil.

Table 10: Peat soils - family classification

Origin	Other diagnostic features		Family
Topogenic	O horizon 10-40 inches deep	Mineral subsoil light-textured	IGAN
		Mineral subsoil heavy-textured	MUKAH
	O horizon more than 40 inches deep		ANDERSON
Climatogenic	O horizon 10-40 inches deep		MULU

5. NOTES ON THE FAMILIES

5.1. Igan. Soils of this family consist of shallow, acid peats, commonly woody or slightly sandy, overlying sand. They are found mainly in coastal areas particularly in Third and Fourth Divisions. Where successfully drained they are used for vegetables, fruit trees and coconuts.

5.2. Mukah. Mukah Family soils are generally shallow, acid peats, a commonly woody or clayey and overlie plastic clays. They border large inland swamps and form many small separate swamps. They are used in many areas for swamp padi, sago and rubber.

5.3. Anderson. These soils are deep, woody, acid peats occupying most large and many small swamps in the lowlands. Their base, in many places, is lower than mean tide level. Recorded depths commonly exceed 20 feet and may exceed 50 feet (ANDERSON, 1964, p.9). They are used in places for sago and, in the lower Rajang area, for rubber

5.4. Mulu. These soils have only been examined at Mulu in Fourth Division; they occur under Moss Forest above 4,000 feet where they rarely exceed 30 inches in depth. By comparison with the lowland peats, the soil is more fibrous, spongy and less waterlogged. They are not used for agriculture.

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RECENT ALLUVIAL SOILS

1. GENERAL

Baldwin et al (1938, p.1001) describe Alluvial soils as stratified soils with little profile development, some accumulated organic matter and a wide range of internal drainage (from poor to good). This concept is followed in Sarawak but the range of drainage conditions is limited to well-drained and imperfectly-drained. Poorly-drained soils are included in the Gley soils.

2. LOCAL DEFINITION

Recent Alluvial soils are mineral soils in which:-

1. an R horizon, or a C horizon, consisting of rock weathered in situ, is not within 10 inches of the base of an O horizon,
2. where the profile consists of bands of coarse and fine earth, there is no band of material with more than 80 per cent coarse earth which is more than 20 inches thick and is within 10 inches of the base of an O horizon,
3. a gley horizon, if present, is not within 20 inches of the base of an O horizon,
4. neither albic nor spondic nor argillic horizons are present.

Where thick bands of coarse earth are present within 10 inches of an O horizon the soil is classed as a Skeletal soil.

3. ENVIRONMENT

3.1. Climate. These soils are found in a 'Tropical Rainy Climate - subclass Af' (KOPPEN, 1916). The rainfall, using Mohr's system (MOHR and VAN BAREN, 1954), is Class 1a, no month having less than 100 mm rainfall.

3.2. Parent material. The parent materials are recent riverine and marine deposits derived from sources varying from igneous and metamorphic rocks to sedimentary rocks. Textures of the parent materials range from gravelly sands to clays. Only where basic igneous or argillaceous rock types are the source, is the clay fraction usually dominant in the alluvium derived from them but there is also a succession along the river courses, from their sources to their lowest points, from coarse textured materials to increasingly more clayey deposits.

The most poorly sorted soils are characteristic of the higher reaches of river courses.

3.3. Topography. These soils are normally found on present levees and riverbanks. They are also found in some small, narrow valleys in interior areas and on alluvial fans. Along the coast the soils are found on recent beaches and sandpits.

3.4. Vegetation. On the riverine families the primary vegetation is mainly Mixed Dipterocarp Forest in which large emergent trees give the impression that it may be of better quality than the more dense forest of the same nature on related upland soils found nearby. Borneo Ironwood (Eusideroxylon sp.) favours the more sandy soils. Wild fruit trees, in particular Illipe Nut (Shorea sp.) are more common than in related Mixed Dipterocarp Forest on the hills.

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4. FAMILY CLASSIFICATION

Families are classified initially on colour. This is indicative of total iron content, which in Sarawak is closely related to many other characteristics such as source material, phosphate fixing power and drainage. A second subdivision is based on origin. A further subdivision is then based on texture, two texture classes being used. Where soils consist of depositional layers of contrasting texture, the dominant texture group is estimated by considering the thickness of each layer (to a depth of 48 inches) and the texture group to which it belongs. Where, however, the surface 20 inches is of one texture group, the texture of deeper layers is not considered.

Table 11: Recent Alluvial soils - family classification

Colour	Parent material	Texture	Families
Hues 7.5 YR or redder; values 5 or less	Riverine	light (1)*	RAMUN
		heavy (1)*	TERBAT
	Marine	light (1)*	SEMATAN
Hues 10YR or yellower; values 5 or less	Riverine	light (1)*	KAYAN
		heavy (1)*	SEDUAU
	Marine	light (1)*	KABONG

5. NOTES ON THE FAMILIES

5.1. Ramun. This family is widespread in First Division, mainly in the Kuching, Upper Sadong and Lundu Districts and is confined to alluvial fans at the debouching points of small streams draining igneous rock massifs. These soils are usually strong brown gravelly clays to sandy loams, with alternating layers of contrasting texture. They are well to excessively drained soils. They are used for a variety of crops but mainly for perennials. Nutrient levels are higher than normal for Sarawak soils.

5.2. Terbat. These soils occur either in association with Ramun soils in alluvial fans or in small narrow valleys close to basic igneous rock massifs. They are mainly found in First Division, in particular in the Serian and Terbat areas. Textures are usually homogenous throughout the profile and the soils are well drained. Colours are usually strong brown to reddish yellow. Physically they are superior to most soils in Sarawak although nutrient levels are lower than those of the related Ramun Family.

5.3. Sematan. This family occurs on the coast between Tanjong Dato and Tanjong Po in First Division, where rock types rich in ferro-magnesium minerals outcrop. From these outcrops eroded materials are distributed along the coast by long-shore drift. Soils of this family are commonly found in association with the younger Kabong Family soils. Sematan soils are brown to reddish yellow in colour, are well drained but have an intermittent watertable between 24 and 48 inches. They contain an abundance of shell fragments particularly in the lower subsoil where in some localities, calcrete has formed.

5.4. Kayan. These soils are widespread in all Divisions where they occur along the upper reaches of rivers draining areas dominantly of arenaceous rock types. They are usually brownish yellow to yellow sandy soils butthin layers of a loamy texture may occur. The soils are not generally used for agriculture because of their low fertility and susceptibility to erosion and flooding.

5.5. Seduau. This family is found throughout Sarawak but the total area covered by it is believed to be small. It occurs in places in small interior valleys overlying consolidated rocks. These soils are brownish yellow heavy loams. Drainage is usually moderately good but underlying rock may give rise to perched water tables in the wet season. Seduau soils are commonly used for rubber if they occur in areas of significant extent.

5.6. Kabong. Soils of this family have developed in young sand bars, spits, and recent beaches along almost the whole coastline of Sarawak except the stretch between Tanjong Po and Kuala Krian. Kabong soils are quartzose but between Tanjong Dato and Tanjong Po contain muscovite, biotite and sericite. In the latter area they are associated with Sematan soils to which they are related. A common feature of Kabong soils is the relatively high total calcium content derived from shell fragments.

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APPENDIX

EXPLANATION OF TERMS USED

For ease of reference the definitions of the main technica terms used in defining the great soil groups and families are give below. In the case of texture some general terms have been defined for local use. These are asterisked in the text above. So points which require clarification but are relevant to a number of groups are included here to avoid duplication in the text.

CLIMATE

Köppen's system. A tropical rainy climate, in this system, is one i which the average annual temperature is at least about 20°C and the annual average rainfall at least 600 mm. Subclass Af climates hav at least 60 mm rainfall in the least rainy month.

Rainfall - Mohr's system. Class la rainfall is defined as a rainfa regime in which all months of the year have more than 100 mm rain, This Class can be described as 'Continuously Wet'.

PARENT MATERIAL

Origin of alluvial parent material. A distinction is made at the family level for many groups between alluvial parent material of re and past origin. For practical purposes recent alluvium is conside that which is actively accumulating and is within reach of present river flooding while old alluvium, or alluvium of past origin, is considered that which is beyond the reach of present river flooding

MINERAL AND ORGANIC SOIL

Mineral soil is considered that which contains less than 35 per cen organic matter. Organic soil contains more than 35 per cent organi matter. For classification purposes no distinction is made between peat and muck, all being termed peat. Where muck is mentioned, the word is used in the sence of finely comminuted woody debris, not in sense of peat with a high percentage of mineral matter.

At the great soil group level soils are classified as 'mineral soil or 'organic soils' on the basis of the horizons below the surface 10 inches.

SOIL DEPTH

For classification purposes the profile is considered only to a dep of 48 inches from the surface or, if an O horizon is present in a mineral soil, from the base of the O horizon. Thus in a definition in the notes on a family 'no spodic horizon', for example, means no spodic horizon within 48 inches of the surface or the base of the O horizon, if an O horizon is present.

SOIL DIAGNOSTIC HORIZONS

O horizon. Horizon: (1) formed or forming in the upper part of mine soils and above the mineral part; (2) dominated by fresh or partly decomposed organic material; and (3) containing more than 30 per cent organic matter if the mineral fraction is more than 50 per cen clay, or more than 20 per cent organic matter if the mineral fractio has no clay. Intermediate clay content requires proportional organic-matter content. (U.S.D.A., 1960, p.25.)

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A horizon. Mineral horizon consisting of :- (1) horizon of organic-matter accumulation formed or forming at or adjacent to the surface; (2) horizon that has lost clay, iron or aluminium with resultant concentration of quartz or other resistant minerals of sand or silt size; or (3) horizon dominated by 1 or 2 above but transitional to an underlying B or C horizon. (U.S.D.A., 1960, p.25).

A1 horizon. Mineral horizon, formed or forming at or adjacent to the surface, in which the feature emphasised is an accumulation of humified organic matter intimately associated with the mineral fraction. (U.S.D.A., 1960, p.25)

A2 horizon. Mineral horizon in which the feature emphasised is loss of clay, iron or aluminium, with resultant concentration of quartz or other resistant minerals in sand and silt sizes. (U.S.D.A., 1960, p.25.)

Albic horizon. A surface or lower horizon having such thin coatings on the sand and silt particles that the hue and chroma of the horizon are determined primarily by the colour of the sand and silt particles. Especially in soils rich in quartz, moist chromas of albic horizons are 3 or less, and dry chromas less than 3. Chromas are lower than those of an underlying argillic horizon, unless the chroma of the argillic horizon is 2 or less. Dry values are higher and moist value usually higher than those of an underlying argillic horizon, and always higher than those of an underlying spodic horizon. An albic horizon usually lies on an argillic horizon, spodic horizon or on a fragipan or an equally impervious horizon or layer. (U.S.D.A., 1960, p.60.)

B horizon. Horizon in which the dominant feature of features is one or more of the following:-

(1) an illuvial concentration of silicate clay, iron aluminium, or humus, alone or in combination;

(2) a residual concentration of sesquioxides or silicate clays, alone or mixed, that has formed by means other than solution and removal of carbonates or more soluble salts;

(3) coatings of sesquioxid, ∠ adequate to give conspicuously darker, stronger or redder colours than overlying and underlying horizons in the same sequum but without apparent illuviation to meet requirements of 1 or 2 in the same sequum; condition in sequums lacking conditions defined in 1, 2 and 3 that obliterates original rock structure, that forms silicate clays, liberates oxides, or both, and that forms granular, blocky or prismatic structure if textures are such that volume changes accompany changes in moisture. (U.S.D.A., 1960, p.26.) ∠ is

B2 horizon. That part of the B horizon where the properties on which the "B" is based are without clearly expressed subordinate characteristics indicating that the horizon to an adjacent overlying A or an adjacent C or R. (U.S.D.A., 1960, p.27.)

Argillic horizon.

An argillic horizon forms below an eluvial horizon but may occur at the surface if a soil has been partially truncated. It meets the following requirements:-

1. Where an eluvial A remains, and there is no lithologic discontinuity between the A and the argillic horizon, it contains more clay than the A as follows:-

a. If the A has less than 15 per cent clay in the fine earth (less than 2 mm.) fraction, the argillic horizon must contain at least 3 per cent more clay than the A. (13 per cent versus 10 per cent, for example.)

b. If the A has more than 15 per cent clay and less than 40 per cent in the fine earth fraction, the ratio of the clay in the argillic horizon to that in the A must be 1.2 or more.

c. If the A has more than 40 per cent clay in the fine earth fraction, the argillic horizon must contain at least 8 per cent more clay than the A. (50 per cent versus 42 per cent, for example.)

2. The argillic horizon must be at least one-tenth the thickness of the sum of all overlying horizons, or more than 15 cm (6 inches) thick; and the clay increases required under item 1 must be reached within a vertical distance of 30 cm (12 inches) or less.

3. If peds are present, an argillic horizon must show clay skins on some of both the vertical and horizontal ped surfaces and in the fine pores, or must show oriented clays in 10 per cent or more of the cross section.

4. If a profile shows a lithologic discontinuity between the A and the argillic horizon, or if only a plow layer overlies the argillic horizon, the argillic horizon need show only clay skins in some fine pores and, if peds exist, on some vertical and horizontal ped surfaces, or the clay skins must constitute approximately 10 per cent of the cross section.

5. The argillic horizon does not necessarily have more clay than the C horizon, but it should have more fine clay than the C.

(U.S.D.A., 1960, pp.44-45.)

Spodic horizon.

A spodic horizon is one which shows the following properties

1. Amorphous coatings of humus and allophane or of humus, allophane, and free sesquioxides on particles of sand or silt, or rounded to subangular pellets of humus or of humus and sesquioxides between 20 and 50 microns in diameter; or both.

2. More than 0.29 per cent organic carbon or 1 per cent free sesquioxides in some part.

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3. No clay skins; under crossed polarizers coatings in thin sections show slight or no birefringence and no extinction on rotation, which indicates substances forming the coatings are not both crystalline and oriented.

4. No structure, or structure other than blocklike; or blocklike structure only if the grade of structure is weak.

5. Carbon-nitrogen ratios of more than 14, if profile is virgin.

6. SiO_2/R_2O_3 ratio in clay fraction less than that in clay fraction of overlying A2 or albic horizon and less than that in clay fraction of parent material.

(U.S.D.A., 1960, p.49.)

Plinthite. Plinthite is defined by the U.S. Department of Agriculture (U.S.D.A., 1960) as the sesquioxide rich, humus poor, highly weathered mixture of clay with quartz and other diluents, which commonly occurs as red mottles, usually in platy, polygonal, or reticulate patterns; plinthite changes irreversibly to hardpans or irregular aggregates on repeated wetting and drying, or it is the hardened relicts of the soft red mottles. The lower boundaries of plinthite are often diffuse or gradual, but they may be abrupt at a lithologic discontinuity.

Plinthite may occur as a constituent of a number of horizons, including ochric and umbric epipedons, argillic horizons, oxic horizons, and C horizons. It is a form of the material which has been called laterite, renamed to obtain a better combining form - for the new nomenclature. It normally forms in horizons below the surface, though it is commonly exposed at the surface, and may, under some conditions, form at the surface. In Sarawak the term 'plinthite' is used only for the hardened form of this material.

C horizon. A mineral horizon or layer, excluding bedrock, that is either like or unlike the material from which the solum is presumed to have formed, relatively little affected by pedogenic processes, and lacking properties diagnostic of A or B but including materials modified by:- (1) weathering outside the zone of major biological activity; (2) reversible cementation, development of brittleness, development of high bulk density, and other properties characteristic of fragipans; (3) gleying; (4) accumulation of calcium or magnesium carbonate or more soluble salts; (5) cementation by such accumulations as calcium or magnesium carbonate or more soluble salts; or (6) cementation by alkali-soluble siliceous material or by iron and silica. (U.S.D.A , 1960, p.28)

R horizon. Underlying consolidated bedrock, such as granite, sandstone, or limestone. If presumed to be like the parent rock from which the adjacent overlying layer or horizon was formed, the symbol R is used alone. If presumed to be unlike the overlying material, the R is preceded by a Roman numeral denoting lithological discontinuity. (U.S.D.A., 1960, p.28.)

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SOIL TEXTURE

Six broad texture classes are recognised, as follows:-

Fragmental soils: Stones, cobbles, gravel, and coarse sand

Sandy soils: Sands other than coarse sand, and loamy sands.

Light loamy soils: Light sandy loams (less than 15 per cent other than light very fine sandy loam; and light loams (less than 15 per cent clay).

Light silty soils: Silt; light silt loam (less than 15 per cent clay); and light very fine sandy loam (less than 15 per cent clay).

Heavy loamy soils: Heavy sandy loams, loams, and silt loam (all with more than 15 percent clay); sandy clay loam; clay loam and silty clay loam.

Fine-textured soils: Clay, silty clay, and sandy clay.

(U.S.D.A., 1960, p.100)

In many great soil groups a distinction is made at the family level between light-textured and heavy-textured soils. Where this single division is made between the classes the descriptive term in the textis followed by the symbol (1)*. Where this symbol is used the following definitions are meant:-

<u>Light-textured (1)* soils.</u> Sandy, light loamy and light silty soils. (Fragmental soils are not included).

<u>Heavy-textured (1)* soils.</u> Heavy loamy and fine textured soils.

Where there is a textural increase down the profile and a textural B horizon is present, classification is made on the texture of the B horizon.

Within the group of Red-Yellow Podsolic soils a division into three texture groups is made in the case of residual soils. Where three texture groups are employed the descriptive term in the textis followed by the symbol (2)* and the following definitions are meant:-

<u>Light-textured (2)* soils.</u> Soils in which the B horizon is sand, light loam, light silt or heavy loam. If heavy loam, the B horizon is heavy sandy loam, heavy loam or sandy clay loam. Silty clay loam and clay loam are excluded.

<u>Medium-textured (2)* soils.</u> Soils in which the B horizon is silty clay loam, clay loam or fine textured but is not clay unless the A2 horizon is sandy clay loam or lighter-textured than sandy clay loam.

<u>Heavy-textured (2)* soils.</u> Soils in which the A2 horizon is clay loam or fine textured and the B horizon is fine textured.

<u>Very firm.</u> Soil material crushes under strong pressure; barely crushable between thumb and forefinger.

<u>Extremely firm.</u> Soil material crushes only under very strong pressure; cannot be crushed between thumb and forefinger and must be broken apart bit by bit.

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Salinity. Three salinity levels are recognised, defined in terms of groundwater conductivity (expressed in mmhos per cm at 25°C) -

non-saline	-	under 500 mmhos
weakly saline	-	500 - 4,000 mmhos
strongly saline	-	over 4,000 mmhos

REFERENCES

ANDERSON, J.A.R.	1963	The flora of the peat swamp forest of Sarawak and Brunei, including a cata of all recorded species of flowerin plants, ferns and fern allies. Gardener's Bull, 20 (2):131-227
ANDERSON, J.A.R.	1964	The structure and development of the peat swamps of Sarawak and Brunei. Journ. Trop. Geog., 18:7-16
ANDERSON, J.A.R.	1965	Limestone habitat in Sarawak. In U.N.E.S.C.O., Proc. of the Symp. on Ecological Research in Humid Tropics Vegetation, 49-57
ANDRIESSE, J.P.	1962	Field Classification of Sarawak soil Sarawak Department of Agriculture, Soils Division, Technical Paper No.1 (cyclostyled).
BALDWIN, M, KELLONG, C.E. and THORP, J.	1938	Soil classification. In: U.S.D.A. Soi and men. U.S.D.A. Yearbook, 979-100
BROWNE, F.G.	1952	The kerangas lands of Sarawak. Malay Forester, 15: 61-73
CLINE, M.G.	1955	Soil survey of the territory of Hawa U.S.D.A. Series 1939: 25.
DAMES, T.G.W.	1955	The soils of East-Central Java. Bogor Contribution of the Gen. Agric Research Stn. No.141
DAMES, T.G.W.	1962	Report to the government of Sarawak soil research in the development of Sarawak. F.A.O. Rpt. 1512
DUDAL, R, and MOORMANN, F.R.	1964	Major soils of southeast Asia. J. Tr Geog. 18: 7-16
KÖPPEN, W.	1916	Klassification fur Klimate, Temperat Niederschlag und Jahreslauf. Paterm. Mitteil., 62: 197-203
MOHR, E.C.J. and van BAREN, F.A.	1964	Tropical soils. N.V. Uitgeverij W. Van Hoeve, The Hague.
NYUN, M.A. and McCALEB, S.B.	1955	The reddish-brown lateritic soils of the North Carolina piedmont region. Soil Science, 80: 27-41
SARAWAK MIN. OF NATURAL RESOURCES	1964	Annual Report of the Research Branch Department of Agriculture, for the year 1962 - 1963. Government Print Kuching.
STEPHENS, C.G.	1956	A manual of Australian soils. Melbo C.S.I.R.O.

.../77

THORP, J. and SMITH, G.D. 1949 Higher categories of soil classification: order, suborder and great soil groups. Soil Science, 67:

U.S.D.A. 1951 Soil survey manual, U.S.D.A., Handbook 18

U.S.D.A. 1960 Soil classification, a comprehensive system: 7th approximation. U.S.D.A. Soil Cons. Serv.

WALL, J.R.D. 1962 Norstrandite in soil from west Sarawak.

WOLFENDEN, E.B. BEARD, E.H. and DEANS, T.D. Borneo. Nature, 196 (1851): 264-265.

WILFORD, G.E. and WALL, J.R.D. 1965 Sarawak karst topography, J. Trop. Geog. (in press).

WOOD, T.W.W. and BECKETT, P.H.T. 1961 Some Sarawak soils, II: soils of the Bintulu coastal region Journ. Soil Sc. 12 (2): 218-233.

DISCUSSION

Thomas: - You have said that the criteria used for distinguishing the soil units at all levels are essentially based on easily recognisable features. But I can see that total P, C.E.C. and group 3 elements have been used to distinguish Families in, for example, Skeletal Soils, Brown Forest Soils and Red-Yellow Podzolic Soils.

Scott: - In most cases we can recognise soil units by their physical features alone but to be safe the chemical properties of the soils are related to their morphology. Chemical characteristics are therefore not used as sole diagnostic criteria but as factual evidence, e.g. weathered basic igneous rocks may not be recognisable as such but total P is used to bring out the evidence, since in Sarawak only soils derived from such parent material have high total P values.

Leamy: - There appears to be no distinction made between mapping and classification units. Does this not lead to considerable difficulties in mapping complex soil landscapes ?

Scott: - The mapping units used in Sarawak consist of a mixture of simple units for the landscape and compound units for the more complex. Probably, whatever mapping unit is used, given a complex soil landscape the final map will be complicated.

Leamy: - This is true, but I feel that you should map what is there, for when you map on classification units there can be bias in the map.

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Andriesse: - Families in most cases correlate with topographic or geological boundries, therefore parent material and topography are used in drawing boundries between families and where this is not possible an association of families is used as a mapping unit. The family is the main mapping unit because it is based on morphological features recognisable in the field. Separation within a family is done on chemical grounds and it is possible that many of the families in Sarawak are equivalent to certain series in Malaya, and some families are equivalent to sub-groups in Malaya.

Guha: - Does chemical analysis used for classification refer to the nutrient status or fertility aspect of the soil or to the soil formation processes e.g. sesquioxide content ? It would be better to base the classification on morphology and soil formation processes rather than on the nutrient status which has to be verified by the Agronomists.

Scott: - Chemical analysis is used mainly as an aid to classification. Nutrient status of Sarawak soils is on the average very low and cannot be used for classifying soils, but total P and total iron, for instance, bring out distinct differences in soils which are tied up with other morphological differences.

Dumanski: - Do you consider that soil chemistry is a more favourable system to classify soils at the series level than soil morphology ?

Andriesse: - If all the morphological criteria have been used in differentiating the soils down to the family level then chemistry has to be used in separating out the series.

Bailey: - Chemistry is used mainly to separate the saline soils at the family level.

Thomas: - In your classification you have not laid any undue importance on parent rock material. Is it true that you have given more importance in your classification to the chemical nature of your soil. For example, you separate your Kapit and Sedong Families according to total phosphorus content. But the Kapit could contain shale, sandstone or granite, whilst Sedong Family basic or intermediate igneous rock material.

Scott: - In practice parent material is used in classifying the soils but chemical data are referred to for further confirmation.

Wong: - To what extent is structure of the soil used in the classification at family level since most of your survey is based on auger borings.

Scott: - Structure has been considered in only one case and that is a laterite soil.

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SOIL CLASSIFICATION IN MALAYA

by

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History

Interest in Malayan soils and their classification can be traced to the early years of this century, but the first overall attempt to relate Malayan soils to great soil groups recognised elsewhere in the world did not appear until the 1950's, when Owen (1951) published a provisional classification of Malayan soils. This was a valuable first assessment but, because of a lack of information about the soils, was inevitably deficient in detail. The implementation of the Schematic-Reconnaissance Soil Survey of Malaya, which aims to provide a complete stocktaking of Malayan soil resources, gradually brought forward new information on the soils and enabled a second, and more comprehensive, overall soil classification to be proposed. This accompanied the 1962 Soil Map of Malaya (Panton, 1964), but was still regarded as tentative because of a lack of precise soil information over large parts of the country. Other authors have contributed by suggesting correlations between soils of certain regions in Malaya and soil groups recognised elsewhere (Joseph 1965), but the application of all the classification proposals made to date has been severely restricted by a lack of data.

This situation is changing daily, and with more than 75% of the land area of Malaya completed on the Schematic-Reconnaissance Soil Survey, it is felt that enough information is now available to justify presenting what might be called the first approximation to a fully comprehensive technical soil classification.

Requirements of a Soil Classification

The main requirements of a technical soil classification are:

1) The categories used should be clearly stated.
In the past, three categories have been employed in Malaya - the soil series, the great soil group and the order. In this approximation two further categories, - the soil family and the suborder are introduced, and the relationship of the five categories is as follows:

SERIES → FAMILY → GREAT SOIL GROUP → SUBORDER → ORDER

2) The names used for soils falling into each category should where possible be terms which have been defined elsewhere and are widely used and understood. Where this is not possible, new terms proposed should be fully defined according to morphological and analytical characteristics. One reason why this present attempt can only be a first approximation is that sufficient analytical data is not yet available.

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The Structure of the Classification

The appearance in 1960 of a comprehensive system of soil classi fication in the Seventh Approximation (Soil Survey Staff 1960) injecte considerable vitality into the international correlation of soils, and, introducing completely new terms, enabled a fresh approach to be made, particularly to the classification of soils in the higher categories. I the past in Malaya, categories above Great Soil Group level have been very broad and are quite inadequate in the light of new information tha has been obtained over recent years. The introduction of Seventh Approx mation terms for Suborders and Orders corrects this inadequacy and also facilitates realistic correlation on an international scale. Unfortunat the Seventh Approximation is also admittedly deficient in information o tropical soils, and the definition of the main relevant order - the oxisols - is incomplete and largely untested. However, a recent paper b Haantjens (1965) contains proposals which largely correct this situatio as far as the Malayan scene is concerned, and his suggestions for the definition and subdivision of the Oxisol order are adhered to in this paper.

Up to the present, soil classification exercises in Malaya have been mainly confined to assigning soil series to Great Soil Groups. The names used for these Groups have been drawn from verious sources, but although they have become well entrenched in soil literature, only rare have they been satisfactory defined. Over recent years several authors and agencies throughout the world have been critically examining these Groups and two recent papers (Dudal and Moormann 1964; World Soil Resou Report 12, 1964) are of particular interest and make feasible an attemp to allot accepted and well-defined Group names to Malayan soils.

Definition of Great Soil Groups

The following definitions, with one exception, are drawn from the two sources mentioned above with slight modification.

REGOSOLS: These soils have little or no profile differentiat and are derived from sediments other than those deposited in water. They typically have an AC profi with the A horizon shallow and merging into uncon- solidated rock material. In Malaya they are found on aeolian sands where profiles are normally devoi of weatherable minerals and subsoils are frequently a whitish pure quartz residue; or on slope colluvi where profiles are mostly of medium texture (sandy loam to clay loam) and may have gravels and stones throughout.

ALLUVIAL SOILS: These are soils with an AC profile formed on recent deposits of fluvial, marine or lacustrine origin. The A horizon is weakly developed and merges into undifferentiated, usually wet, mineral material often showing evidence of reduction (gley). Alluvial soils may regularly receive additions of fresh sediments. Most Alluvial Soils in Malaya are not well drained and are dominantly greyish colour with distinct mottling throughout their profiles. However, better drained soils on levees are of common occurence and these are normally light textured and brownish or yellow brown throughout.

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ACID SULPHATE SOILS: Acid sulphate soils are usually formed from recent fluvial or marine deposits in brackish water or on tidal flats, and an important feature is their high content of sulphides which causes severe acidification upon drainage. They have an ACr profile in which the A horizon, which may have a relatively high content of organic matter, rests upon undifferentiated, wet, mineral material showing evidence of strong reduction, and usually having greenish grey colours and a distinctive sulphurous odour.

PODZOLS: These are soils with an ABC profile. The Ah* horizon overlies a strongly bleached Ae horizon, the thickness of which varies widely. The B horizon shows an accumulation of iron, organic matter, or both. In Malaya these soils are always light and usually very sandy in texture. They are most extensive on the old coastal sand deposits of the east coast, but have also been identified on granite at high altitudes (4000 ft.)

LOW HUMIC GLEY SOILS: These soils are developed on alluvial or colluvial parent materials of riverine or marine origin. They occur generally in poorly drained locations and are characterised by gleying throughout the profile or gleying immediately below the surface. They normally have a thin, not very dark, Ah horizon and a textural B horizon which frequently shows conspicuous strong mottles. Undisturbed profiles normally show an Ah/Ae/Btg horizon sequence.

RED-YELLOW PODZOLIC SOILS: These soils form on non-basic parent materials and have an ABC horizonation. Generally, the Ah horizon has a weak structure and overlies a pale Ae horizon which merges into a strong yellow or red Bt horizon with a subangular blocky structure. Clay movement is indicated by coatings on structural faces. The clay is of the kaolin group and the lower part of the profile often shows mottling and may contain iron concretions. In Malaya, the A/B horizon differences are not nearly as marked as in most areas where these soils occur and it is suggested that the following requirements be regarded as essential for this group:

(1) An Ae/Bt horizon sequence recognised in the field by a change in colour (usually from yellower to redder hue, or from lower to higher chroma), and an increase of clay in the Bt as gauged by texture assessment.

(2) If the Ae has less than 15% clay, the Bt must contain at least 3% more clay; if the Ae has between 15% and 40% clay the ratio of the clay in the Bt to clay in the Ae must be 1.2 or more; and if the Ae has more than 40% clay the Bt must contain at least 8% more clay than the Ae. This is one of the requirements for an argillic horizon in the Seventh Approximation (Soil Survey Staff, 1960).

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* Horizon designations quoted in this paper follow those defined by Leamy and Panton (1966).

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REDDISH-BROWN LATERITIC SOILS:

These soils are developed on parent materials moderately high in iron and have an ABC profil The B horizon is normally reddish brown, yellowish red or dark red with a subangular blocky structure and clay coatings on structur ped surfaces. There is commonly an Aej/Btj horizon sequence, but this may be Ae/Bt on morphological criteria. However, the clay increase required for Red Yellow Podzolic soil is not normally evident.

FERRUGINOUS TROPICAL SOILS:

These are soils with an ABC profile in which the B horizon is characterised by laterite concretions, either nodular or massive. The concretionary layer normally commences within 3 feet of the surface and is thicker than 2 fe It contains more than 50% gravel consisting of oxides and/or quartz, or continuous massive laterite. An Ae/Bt horizon sequence may be present above the concretionary layer which usually grades below into a variegated clay.

Note: Considerable modification has been made here to the definition of these soils outlined in World Soil Resource Report No.12, and it may eventually be necessary to change the name of this group in Malaya.

YELLOW-GREY PODZOLIC SOILS: This name is introduced here to accomodate those soils with predominantly pale colours normally developed on strongly weathered argillaceous rocks, but also found on some aci igneous rocks. They are similar in some featur to the Grey Podzolic Soils (Dudal and Moorman 1964), but overall differences seem too great allow them into that group. They are character by brownish yellow, pale yellow to pale grey colours and normally have strong horizon devel ment. A compacted subsoil layer is typical and moderately and strongly developed B horizon structures, which are usually blocky or prismat often occur. Strongly developed Bt horizons wit almost continuous clayskins along ped surfaces are invariably present, and are often, but not always, overlain by distinct Ae horizons. A distinct to indistinct band of laterite con- cretions is commonly present and often overlie variegated heavy clay. Apart from the laterite concretions, total iron oxide content of these soils is low to very low.

GREY PODZOLIC SOILS:

These soils have weakly developed horizons and field evidence for an Ae/Bt horizon sequence is often not strong. They are commonly formed on alluvial materials with a high sand content, and are characterised by fairly uniform light grey colours throughout.

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FERRALSOLS: This replaces the term latosols and was introduced in World Soil Resource Report No.12 The soils have an ABC profile in which the A horizon merges almost imperceptibly into a deep, friable, porous B horizon of high sesquioxide content, low silt content and with very fine, stable aggregation. The B horizon ranges in colour from red to yellow and brown. It does not normally show evidence of clay movement although clay content may increase with depth, and the Ae/Bt horizon sequence typical of the Red-Yellow Podzolics does not occur. A diagnostic feature of these profiles in their indistinct horizon boundaries. The reserve of weatherable minerals is very low and the soils are deep. Further sub groups of the Ferralsols are:

DARK-RED FERRALSOLS: These soils have dark reddish brown, dark brown to dark red colours, a high percentage of sesquioxides, and a high clay content (always more than 50% and normally greater than 70%) throughout. They are developed from parent materials rich in ferro-magnesian minerals.

RED-YELLOW FERRALSOLS: These soils range in colour from deep red to strong brown, and have a high clay content and a moderately high sesquioxide percentage.

PALE YELLOW FERRALSOLS: These soils have a strong brown, yellowish brown or brownish yellow colour. They have a friable B horizon of medium porosity which commonly has weakly developed blocky structures. They have a low percentage of iron sesquioxides and a high percentage of kaolin minerals in the clay. They are formed on parent materials with a low content of ferromagnesian minerals, and have been identified mainly on old alluvial deposits.

ORGANIC SOILS: This group includes the peat soils and organic clays and mucks characterised by thick surface horizons with a high percentage of organic matter, which may overlie gleyed or completely reduced mineral horizons.

Intergrades: Some Malayan soils have properties of more than one of the above groups and are allotted to intergrades between two groups.

The category of Soil Family has been introduced recently in Malaya. This is a grouping together of similar series and although the concept has not been thoroughly tested in practice, at present all series within one family have broad similarities of parent material; there are no great differences in the kind and arrangement of genetic horizons within the profile; and the mineralogy of the soil is similar.

The following table shows the structure of the classification as proposed in this paper, from Families to Orders. Under Great Soil Groups, the Seventh Approximation terminology is shown in brackets after the proposed group name. The subdivision and naming within the Oxisol order follows closely the proposals made by Haantjens (1965). In the other orders use has been made of the Draft Amendments to the Seventh Approximation dated June 1964, and of personal communications from Dr. Guy D. Smith, U.S.D.A.

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TABLE 1: THE STRUCTURE OF THE TECHNICAL CLASSIFICATION

ORDER	SUBORDER	GREAT SOIL GROUP	FAMILY
OXISOL	ARGOX	REDDISH-BROWN LATERITIC SOILS (Normargox)	Kampong Kolam Jempol Munchong
	ACROX	DARK RED FERRALSOLS (Normacrox)	Kuantan Langkawi
		RED-YELLOW FERRALSOLS (Normacrox)	Segamat Patang
	HAPLOX	FERRUGINOUS TROPICAL SOILS (Petraplox)	Malacca Tavy Pokok Sena
		PALE YELLOW FERRALSOLS (Normaplox)	Holyrood Rasau Harimau
ULTISOL	UDULT	RED-YELLOW PODZOLIC SOILS (Tropudult)	Rengam Serdang
		INTERGRADE RED-YELLOW PODZOLIC - YELLOW-GREY PODZOLIC	Durian
		YELLOW-GREY PODZOLIC SOILS (Plinthudult)	Kulai Pohoi Batu Anam
	AQUULT	GREY PODZOLIC SOILS (Tropaquult)	Bukit Tuku
		LOW HUMIC GLEY SOILS (Ochraquult)	Rusila Manik
SPODOSOL	HUMOD	PODZOLS (Normihumod)	Rudua
ENTISOL	UDENT	ALLUVIAL SOILS (Hapludent)	Telemong
	AQUENT	ALLUVIAL SOILS (Haplaquent)	Briah Selangor
		ACID SULPHATE SOILS (Hydraquent)	Kranji
	PSAMMENT	REGOSOLS (Quarzopsamment)	Jambu
HISTOSOLS		ORGANIC SOILS	Peat Organic Clays and Mucks

REFERENCES

DUDAL, R. and MOORMANN, F.R. 1964: Major Soils of South-East Asia. Journal of Tropical Geography, Vol. 18 pp. 54 - 80.

FAO World Soil Resource Report 12, 1964: Preliminary Definitions, Legend and Correlation Table for the Soil Map of the World FAO/UNESCO.

HAANTJENS, H.A. 1965: The Classification of Oxisols (Latosols), Technical Memorandum 65/5 CSIRO Division of Land Research and Regional Survey, Canberra.

JOSEPH, K.T. 1965: The Reconnaissance Soil Survey of Kedah. Division of Agriculture Bulletin No.117, Ministry of Agriculture and Co-operatives, Malaysia 39 pp.

LEAMY, M.L. and PANTON, W.P. 1966: A Soil Survey Manual for Malayan Conditions. Division of Agriculture Bulletin No.119, Ministry of Agriculture and Co-operatives, Malaysia.

OWEN, G. 1951: A Provisional Classification of Malayan Soils. Journal of Soil Science, Vol. 2 pp.20 - 42.

PANTON, W.P. 1964: The 1962 Soil Map of Malaya. Journal of Tropical Geography, Vol. 18, pp. 119 - 124.

SOIL SURVEY STAFF, 1960 and Amendments 1964: Soil Classification A Comprehensive System, 7th Approximation Soil Conservation Service, U.S.D.A.

DISCUSSION

Andriesse: - What is your opinion on the ommission of sesquioxide content from the oxic horizon definition by Haantjens. In Sarawak it would be more important to keep it in.

Leamy: - We agree that the sesquioxide content should be included in the definition of the oxic horizon.

Andriesse: - Are the Sarawak saline gley soils included in the definition of the Acid Sulphate soils of Malaya and are these extensive enough in Malaya to justify a separate grouping.

Leamy: - The definition of Acid Sulphate soils of Malaya would include saline gley soils but these are secondary to the acid sulphate conditions which produce distinct morphological features viz. yellowing in the grey-green subsoil. These acid sulphate conditions are more permanent and produce serious problems in agriculture; they are also extensive enough to form a separate grouping.

Andriesse: - How low are the humus contents in your Low Humic Gley Soils?

Leamy: - This has not been specified yet but we do not anticipate difficulty in defining them judging from our present knowledge.

Andriesse: - Would you agree that borrowing of genetic names could lead to much confusion and it would be better to use 7th Approx. Nomenclature.

Leamy: - Yes, since the 7th Approximation terms carry more significance but we have to bear in mind that these terms are not very meaningful to common users of soil.

Scott: - Regarding Regosols on alluvial and colluvial soils in Sarawak, soils on colluvium are generally more related to associated residual soils than alluvial soils. There is also a difficulty in some cases of recognising the colluvial origin. It would possibly cause less trouble to confine Regosols to these on aeolian alluvium and considering such soils on colluvium in relation to associated alluvial and residual soils.

Thomas: - In Sabah we have restricted the term Regosols, for much the same reasons, to active marine alluvium.

Leamy: - From the point of genetic homogeneity the colluvial soils of Malaya are much more related to the associated Great Soil Groups.

A SCHEME FOR THE CLASSIFICATION OF MALAYAN SOILS.

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Any system of classification, if it is to be fully effective must demonstrate relationships between various groups within the Scheme. The purpose of this paper is to put forward a scheme of classification in which the soils of Malaya (described in the bulletins published previously), have been grouped together in accordance with certain criteria which have been set up to denote various catagorical levels within the scheme. This is done by making an orderly appraisal of the properties of all known soils and sorting out a number of individual morphological appraisals of separate profiles into distinct categories of similar soils referred to as soil types and these, in turn are fitted successively into increasingly broader categories termed soil series, families, great soil groups, suborders and orders similar to the botanical system which passes from species through genera great families, suborders and orders. This taxonomic characteristic indicates relationships between the soils and could also facilitate the mapping of soils at different degrees of detail. In Leamy and Panton's system (1965) a number of serious discrepancies appear. Geology is over-emphasized and the overall effect of climate ignored in many instances. It should be emphasized that the final arbiter is the soil profile itself. Geology or the parent material is only significant at the 'series level' in the scheme proposed hereunder. In Leamy and Panton's scheme we have for instance the Langkawi family embracing the Langkawi, Kaki Bukit and Kodiang Series. The family as you are all no doubt aware is theoretically a close group and must by definition indicate very strong kinship. An examination of the properties of these three soils will indicate however some very startling differences between them. In the author's view the differences between the Langkawi and the Kodiang Series outweigh the differences between any of the sedentary soils of Malaya. In the Kodiang series, there is laterite, a pedological consequence of some significance, the exchangeable Ca^{++} values are very markedly different (6.22 meq/100 gm. compared with 0.37 meq/100 gm.) and so are the base saturation values. To group these soils together at the family level is to ignore the concept of soil genesis. There is far too much confusion in Leamy and Panton's scheme and for this reason the author has attempted to put forward an alternative classification which although premature will denote a better degree of relationship between the groups. From an examination of the properties of soils described in Malaya, a number of morphological properties have been selected in order of their relative importance as the determinant morphological criteria for each of the categories set up. It is essential that the determinant properties at a higher level in the scheme should include or influence strongly the properties recorded at lower levels.

The determinant morphological attributes chosen for each of the categories are as follows.

Soil orders

These differences in the orders Pedocals and Non-pedocals are associated with the presence or absence of lime in the A or B horizons. For the soil suborders, of which there are 6 in the scheme, such things as profile differentiation, position of horizons and drainage are determinants. Differences in Great Soil Groups are associated with differences in profile colour, texture, consistence, structure and the presence of laterite. Differences in families are associated with minor differences in texture and structure. Differences in soil series are associated with differences in parent material and drainage status. Soil types are associated with differences in texture of the A horizon with some minor differences in the lower horizons. For Malayan soils we have pedocals and non pedocals. Apart from the Yen series which is a Rendzina, (Pedocal), the majority of soils are non-pedocals. The non-pedocals can be further subdivided into 6 suborders. These are as follows.

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Suborders

(1) Free draining, solum acid showing only sedimentary horizons.

(2) Free draining, solum acid profile shallow and stony.

(3) Free draining, solum acid with no or very little profile differentiation.

(4) Free draining, solum acid with sesquioxidic illuvial horizon.

(5) Free draining, solum acid with organic and sesquioxidic illuvial horizons.

(6) Soils with impeded drainage (soils influenced by presence of a permanent or periodic water table).

Suborder (1)

Free draining, solum acid showing only sedimentary horizons. In this suborder, we have the following Great Soil Groups
(a) Fluvial soils
(b) Beach deposits

Fluvial soils: These alluvial soils are so juvenile that the soil forming processes have had no time to function except for some organic matter accumulation in the surface. They are texturally variable, usually light textured fine sandy loams. These soils are sedimentary deposits made by water moving at various rates, the texture of the material being determined largely by the velocity of water. These soils are found along the banks of the main rivers of Malaya.
Example: Telemong Series.

(b) Beach deposits (Bris soils) are found in the East Coast where sedimentation of material brought down by the rivers takes place in an environment of constant turmoil (unlike the quiet West Coast, where the finer material is deposited - hence you find mangrove swamps on heavy clays all along the West Coast). The open South China Sea and especially during the period of the North East Monsoons, is constantly churning up the material brought down by the rivers and hence only the heavier coarse grained material is allowed to settle.
Example: Rudua series.

Suborder (2):

Free draining, Solum acid, profile shallow and stony.

In this suborder, we have only one great soil group - the LITHOSOLS. These are skeletal soils. Here soil loss barely keeps pace with soil formation. These are found in the steep topographical situations.
Example: Bukit Temiang series.

Suborder (3):

Free draining, solum acid, with little profile differentiation. Kaolinite is the dominant clay mineral. In this suborder, we have 2 Great Soil Groups:-

(a) The Latosols
(b) The Krasnozems.

The latosols comprise the vast majority of our sedentary soils. Apart from some organic matter accumulation in the surface, the profile shows very little horizon differentiation, apart from slight increases in the clay as one goes down the profile (although this difference is hardly detectable by feel). There may also be slight increases in the

intensity of coloration, but this could be due to the different degree of hydration of iron compounds in the lower parts of the profile. C.E.C. values are about 10 meq/100 gm. of soil in the surface layers.
Example: Rengam series, Munchong series, Kaki Bukit series etc.

Krasnozems

Although these soils are clays they are extremely friable soils. Again, apart from some organic matter accumulation on the surface there is very little eluviation of clay, because of the flocculating effect of the high content of hydrated ferric oxide in the case of the Kuantan Series and the high exch Ca^{++} levels in the case of the Langkawi Series. (A soil series distinguishable, within any Great Soil Group on the basis of parent material.) These soils have a much higher phosphate status than any of the sedentary soils. Cation Exchange Capacity Values are higher than in the latosols and are in the range 15-20 meq/100 gm. of soil in the surface layers. They can be regarded as the richest sedentary soils of Malaya. Their distribution however is exceedingly limited.
Examples: Kuantan and Langkawi Series.

Suborder (4):

Free draining, solum acid with sesquioxidic illuvial (B) horizon.

Here we have at the Great Soil level the Lateritic Latosols. These soils have a low Cation Exchange Capacity of the order of 10 meq/100 gm. of soil or less. In addition to the characteristics of the latosols these soils have a lateritic layer which can be either in the form of pisolithic concretions or a massive impenetrable horizon. A number of soils at the Series level belong to this group, the main ones being Malacca Series, Gajah Mati Series, Chungloon Series, Padang Besar Series, Tandak Series, and Kodiang Series.

Suborder (5):

Solum acid with organic, sesquioxide illuvial (B) horizons.

Here we have one great soil group - the ground water podsols. Podsols are soils which are associated with the wet, temperate regions of the world. The podsol profile is made up of decomposing residues of vegetation overlying a bleached ashy grey layer from which practically everything has been dissolved away by the action of organic acids produced from the decay of organic matter on the surface except silica. The material dissolved away also includes iron and aluminium compounds which is carried downwards by percolating water and deposited in another quite distinct dark brown layer which is compact and which is referred to for obvious reasons as 'coffee rock'. The water table which is an essential feature of the ground water or humus podsols is commonly found just below the coffee rock zone.

In temperate countries podsols can be found under coniferous forests. Nevertheless good examples of podsols can also be found on heath land. In Malaya, ground water podsols are only found in very restricted areas in the Dungun area of the East Coast. These have been developed, close to the rivers on beach deposits on very acid or siliceous parent material. The role of organic acids or some fraction of the acid humus in mobilising sesquioxides and organic matter to produce a differentiation of sesquioxides and organic matter down the profile is of prime importance. Organic matter decomposition under conditions of tropical temperatures and suitable moisture is however very rapid and complete, breaking down to the ultimate oxidation products, carbon dioxide and water without the acidic intermediate compounds having anything but a transient existence. For this reason, the low water holding capacity of these sandy soils in an environment of seasonality of rainfall might explain the presence of the humus podsol in the tropics.
Example: Dungun Series.

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Suborder (6):

Soils with impeded drainage, presence of permanent or periodic intermittent water table in the profile.

In this suborder, we have the following Great Soil Groups:-

1) Peat
2) Low humic glei
3) Acid swamp soils

Peat

Peat is the result of accumulation of organic matter, decomposing processes are inhibited by anerobic or very acid conditions or both. Here organic remains are sufficiently fresh and mineral matter is very low indeed.

The Low Humic Gley

These soils are clays which have been formed under a marine environment and consequently are rich. They have a high percentage base saturation of the order of 60% and total Cation Exchange Capacities over 30 meq/100 gm. in the surface layers. Organic matter levels are high. A feature of these soils with varing degrees of drainage is the presence of a mottled zone resting on bluish grey to olive clay. They are well endowed with the major and minor nutrient elements.
Examples: Selangor Series, Pengkalan Kundor Series etc.

The Acid Swamp Soils

These are texturally, very variable ranging from peaty sands to clays. They are acid soils found in a variety of situations in river terraces, valley tracts, wide river basins, in lagoon and coastal swamps. Most of these soils have been formed under brackish water conditions hence they are much poorer than the soils which have been formed under a marine enviroment (sea water is a salt solution). These soils are also invariably characterised by a highly mottled horizon in the profile.
Examples: Kg. Telok Series, Rusila Series.

See Appendix A and B for illustrations of the proposed scheme.

Appendix A

Rengam coarse sandy clay loam	(Soil type level)
↓	
Rengam Series	(SERIES - level)
↓	
Rengam family which includes the Rengam, Jerangau, Kampong Kolam and Baling series	
↓	
Latosols	(Great Soil Grouping)
↓	
Suborder 3	(Free draining, Solum acid, with little profile differentiation, Kaolinite dominant clay mineral)
↓	
NON PEDOCAL	(Order level)

Appendix B

A few examples are cited for illustrative purposes only. It should be emphasied that this scheme needs further careful study and some adaptation.

Order Non-Pedocals

Suborder (6)	Great Soil Group	*Soil SERIES
	Low humic glei	Selangor Kangkong Pengkalan Kundor
	Acid Swamp soils	Sogomana Manik Bukit Tuku Jaray Briah Perak Rusila Kampong Dusu Penor Telok Kranji Limau Kampong Cherang Hangus Lati Padang Gong Chenak
Suborder (1)	Fluvial soils	Telaga Chemor Telemong Sg. Buloh

* Soil Series determined largely on drainage status.

Appendix C

Dungun Series (Approx. 5 miles from Dungun)

A_1	0" - 6"	Very dark grey sand
A_2	6" - 12"	5y 5/1 Grey sand
A_3	12" - 18"	2.5y 6/2 Light brownish grey sand
B_1	18½" to 20"	2.5y 2/0 Black sand (organic matter and iron compregnated)
B_2	20" - 30"	10R 3/3 dark red sand
B_3	30" - 40"	2.5y 6/4 Light yellowish brown sand with some mottling (white mottles)

COMMENTS

The paper was read for Mr. K.T. Joseph by Dr Ng Siew Kee.

Leamy: - In the scheme that I presented geology is used as a separating criterion up to family level and above family level profile morphology is more important than geology.

The point raised in the paper regarding the Langkawi Family is quite valid for we have noticed the distinct morphological differences in the other two series but the Langkawi soils have been found to be very limited in extent.

The structure of the classification at the order level seems to be rather imbalanced.

LABORATORY DATA AND CLASSIFICATION OF MALAYAN SOILS

By

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INTRODUCTION

A scientific soil classification system would display a logical arrangement and interrelationship of the soils therein and their differentiation should be based on definable and measurable soil properties. The genetic system of soil classification begins from the top and pre-ordains that certain soils must exist under a certain set of environmental conditi While the general concept is sound enough, its rather inflexibility has led to much confusion and controversy which was also partly due to the lac of comprehensive soil data. The 7th approximation (1960) can be said to b a notable landmark in the evolution of soil classification because it places greater emphasis on the soil morphological characteristics and quantitative data than on the factors of soil formation.

Unfortunately for us, the 7th approximation and its amendment deal more with soils of the temperate regions than those in the tropics. This largely reflects the meagre amount of analytical data with pedological significance available to aid the classification of tropical soils and can be partially accounted for by the fact that most soil laboratories in the tropics are geared to studies on soil fertility and plant nutrient requirements. However, in Malaya, it has been increasingly felt that a great opportunity will be lost if current soil surveys are not complemented by soil analysis so that quantitative criteria can aid classification of the soils mapped.

The data presented in this paper, although not as detailed as desired, are used to evaluate the classification of Malayan soils by Leam (1966). This separate treatment is done deliberately in order to ascertain the degree of correlation between field and laboratory data.

Choice of Analytical Data

Prior consideration of available data has indicated that the foll criteria are most useful in differentiating Malayan soils at this stage. These are:-

(a) Clay content in relation to movement
(b) 'Total' iron content
(c) 'Total' element contents
(d) Cation exchange capacity and base saturation
(e) Clay mineralogy.

In appraising these data, the factor of <u>variation</u> is fully borne in mind. Almost all the soils chosen are <u>modal profiles</u> and if no major analytical differences are found amongst them, then the obvious conclusion must be that the laboratory differential used are ineffective.

Clay Content

Field assessment of texture by experienced soil surveyors is usual reasonably accurate but laboratory determination is necessary to confirm this as well as features such as presence of Bt horizons. Clay distributi in profiles of Malayan soils belonging to various great soil groups in the Oxisol and Ultisol Orders (Leamy) is depicted in Figure 1. Bt horizons are distinctly to moderately developed in the red yellow podsolics (RYP) and yellow grey podzolics (YGP) but are not detectable in the dark red ferralsols (DRF) and red yellow ferralsols (RYF). In the reddish brown lateritic group (RBL), there is no evidence of a Bt horizon in Munchong but in Jerangau and Kg. Kolam, clay illuvial horizons are weakly to moderately developed suggesting their proximity to RYP. In the pale yellow ferralsols (PYF), a Bt horizon is distinct in Harimau, indicating that it would be better classed with the RYP.

'Total' Iron Content

Colour has a dominant place in classification as evidenced by the nomenclature of the Great Soil Groups in the Oxisols and Ultisols, and since it is usually related to iron content (not per se because the form of iron compound is also significant), the iron content is considered next to clay. Moreover, evidence of iron movement besides that of clay is one of the conditions for the RYP.

'Total' iron was estimated by extraction with 6 N HCl after ignition. Free iron oxide determination would have been preferable but circumstances did not permit this. However, in view of the fact that most of the non-alluvial soils of Malaya are highly weathered and the iron is rather well dispersed over the soil particles, the 'total' iron content would probably comprise a preponderant portion of free iron oxides.

'Total' iron oxide (Fe_2O_3) contents in Oxisols and Ultisols are shown in Figure 2. Values of ferruginous tropical soils (FTS) are not given but in view of the dominance of laterite or iron concretions in these soils, they can be safely assumed to have the highest contents of total iron oxides. The descending order of total iron contents in Malayan soils is as follows:-

FTS $\gg$ DRF $\gg$ RYF $\gg$ RBL $\gg$ RYP $\gg$ YGP $\gg$ PYF/LHG.

The alluvial soils contain 2.5 - 5.0% Fe_2O_3 and would fall with the RYP in this iron sequence.

It can be seen that total iron oxide content is a good general differentia of Malayan soils. The iron enrichment in the Bt horizons of Rengam and Serdang is clearly shown and the data also confirm the earlier opinion that Harimau should be in the RYP. In addition, iron enrichment in the B horizon of Jerangau (RBL) is also prominent, again indicating its close relationship with the RYP. The iron distribution in the Kg. Kolam and Jempol suggests that their grouping in the RBL needs review and further confirmatory data.

'Total' Elements

These are extracted in the same manner as for iron and the results for P, Ca, Mg, K and Cr are given in Table 1.

The phosphorus values can differentiate the DRF, RYF and alluvial soils but not easily the other soil groups. Calcium and magnesium contents are less effective as criteria for differentiation only the alluvial soils are clearly distinguished. The rather low calcium and magnesium contents in the Kuantan are striking andindicate the senility of this soil. On the other hand the relatively higher calcium, magnesium as well as potassium contents in the Jempol show that it is probably younger than the other soils in the RBL group. Potassium figures are a more useful guide - Allu./RYP-YGP/YGP $\gg$ RBL (Except Jempol) $\gg$ RYF/LHC $\gg$ DRF/PYF/RYP. There is also reasonable differentiation within the Allu. and YGP groups.

The Cr results are included in order to demonstrate that it has good prospects of being a very useful differentia.

TABLE 1

'TOTAL' ELEMENT CONTENTS IN MODAL SOIL PROFILES

G. Soil Group	Series	P		Ca		Mg		K		C
		p.p.m.		m.e. / 100 g.						—
		(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	p.
DRF	Kuantan	535	534	3.08	2.74	2.38	2.07	.64	.48	420-
RYF	Segamat	480	290	3.36	2.61	5.36	4.88	1.97	1.34	-
RBL	Jerangau	211	229	2.72	2.56	3.80	3.80	3.13	3.01	10-
	Kg. Kolam	155	88	3.52	3.45	5.16	4.94	1.28	0.58	-
	Munchong	92	83	0.71	0.43	2.75	2.98	4.86	4.32	40-
	Jempol	115	106	6.64	4.45	7.68	9.36	3.25	15.5	-
PYF	Harimau	52	71	1.36	1.97	4.56	3.83	0.64	0.32	-
	Holyrood	98	75	1.36	1.36	4.20	1.92	0.32	0.32	1-
RYP	Rengam	190	127	1.68	1.47	4.12	3.26	0.96	0.64	3-
	Serdang	60	52	1.36	4.05	4.78	3.91	0.32	0.43	5-
RYP-YGP	Durian	46	36	3.28	3.42	4.96	6.02	13.4	18.8	-
YGP	Kulai	86	87	2.88	1 87	7.16	3.15	4.74	6.09	-
	Batu Anam	80	41	0.68	1.23	2.84	2.15	12.5	13.8	-
LHG	Manik	83	137	1.00	0.41	2.75	4.44	1.82	1.66	13-
ALLU.	Briah	225	130	5.88	5.04	12.4	18.5	7.09	7.68	65-
	Selangor	580	393	7.68	7.51	4.16	16.6	12.5	15.6	90-

* (a) Mean of Top Soil (b) Mean of subsoil horizons # Range in profile.

Cation Exchange Capacity and Base Saturation

Figure 3 (a) indicates generally that C.E.C. values have limited scope as a differentia. The Allu. soil group is well demarcated and the lowest values tend to be found in the PYF and RYP. The remaining soil groups fall into a sub-intermediate category although the top soils of Kuantan, Segamat and Jempol tend to have higher values.

Base saturation values follow the general pattern given by C.E.C. values but are slightly less distinctive. Only the alluvial soils are well differentiated. The remainder have values between 4-11 in the sub-soil horizons and intra-variation rules out any meaningful segregation.

Clay Mineralogy

Very limited data on clay minerals are available but from the foregoing it can be foreseen that in most of the soils, kaolin would be the dominant mineral in the clay fraction. Some approximate semi-quantitative results are given in Table 2.

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FIG.1. CLAY RROFILES OF MAJOR MALAYAN OXISOLS AND ULTISOLS

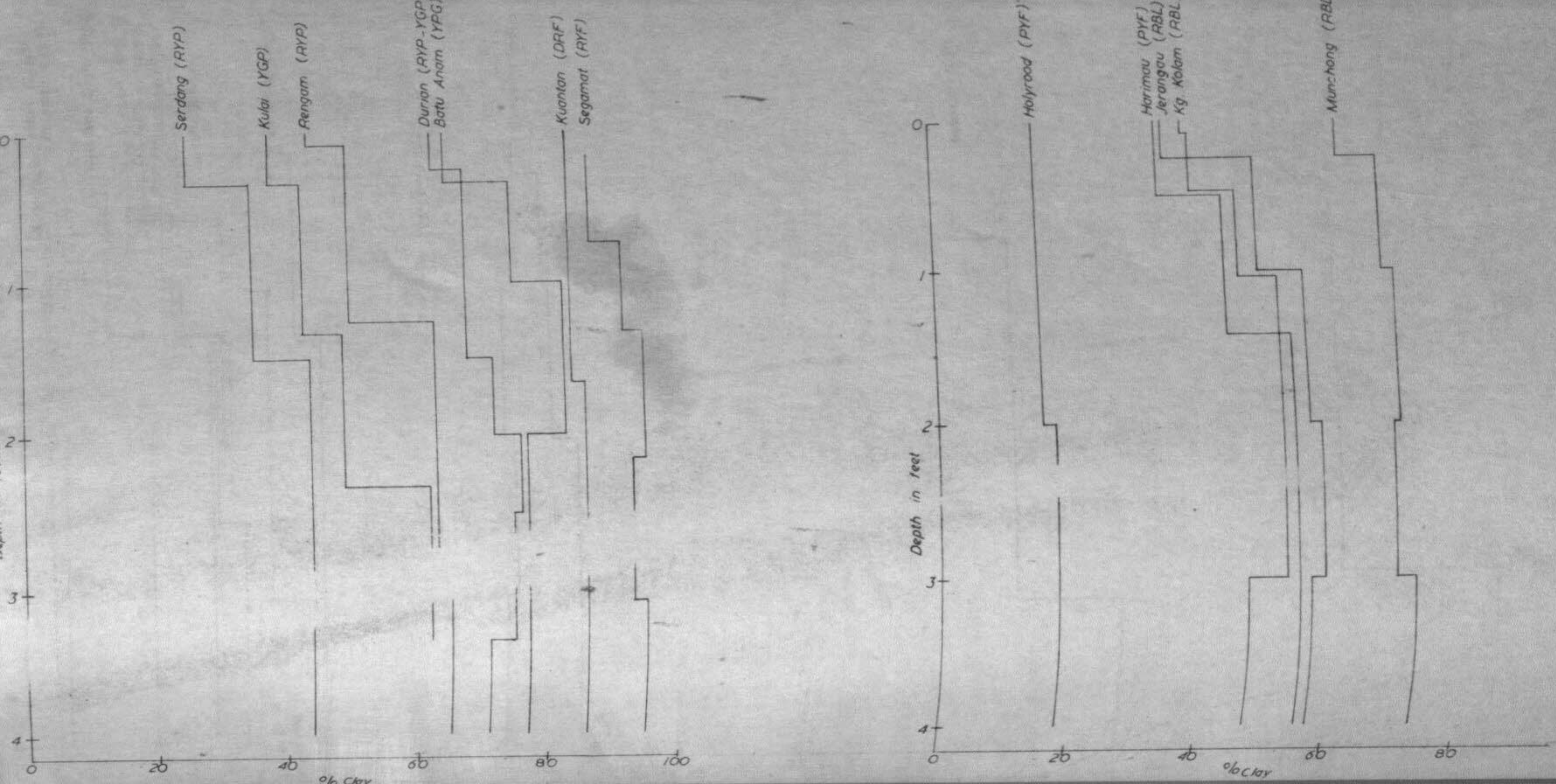

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FIG:2. TOTAL Fe_2O_3 CONTENT IN OXISOLS AND ULTISOLS.

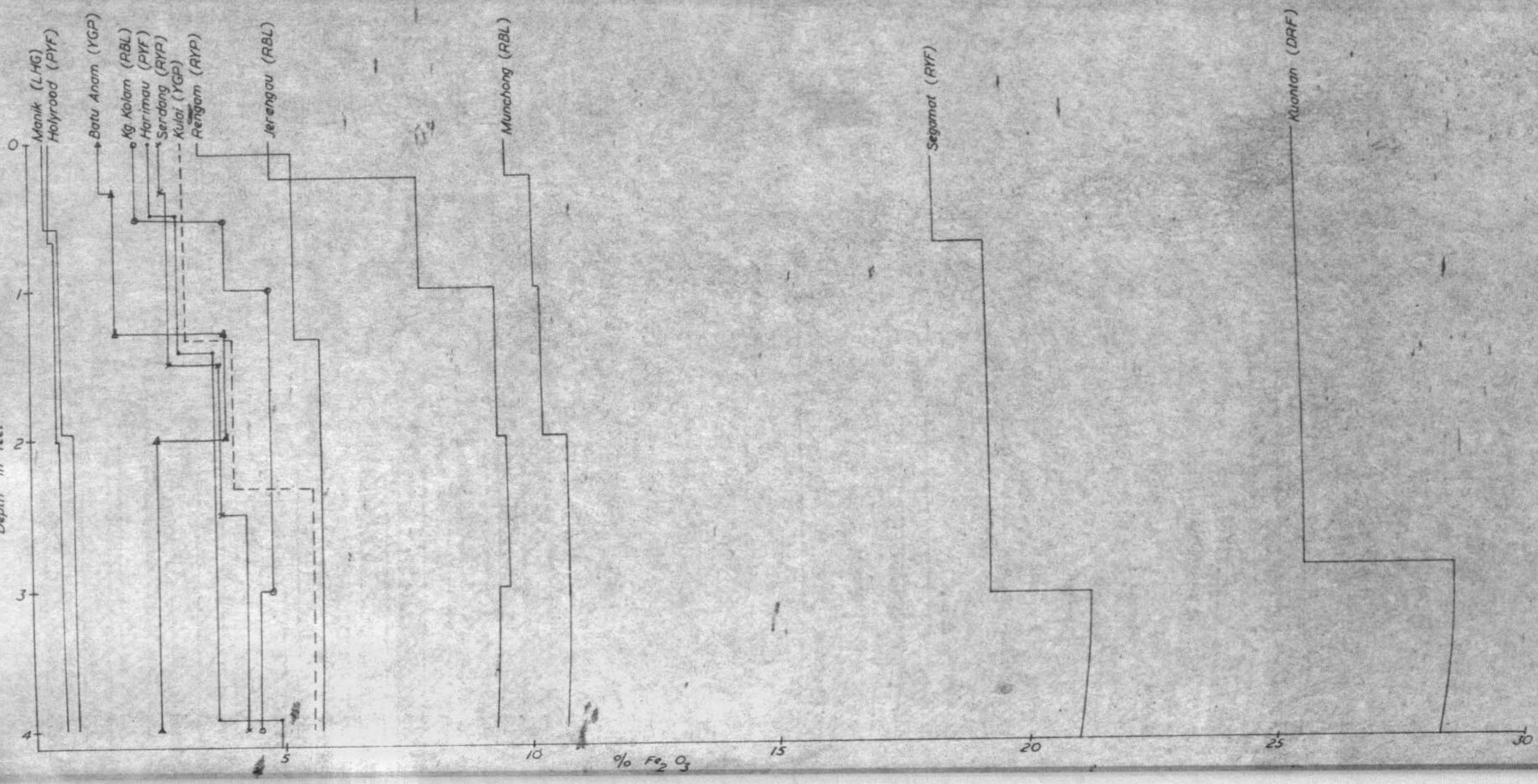

FIG. 3(a) CATION EXCHANGE CAPACITY.

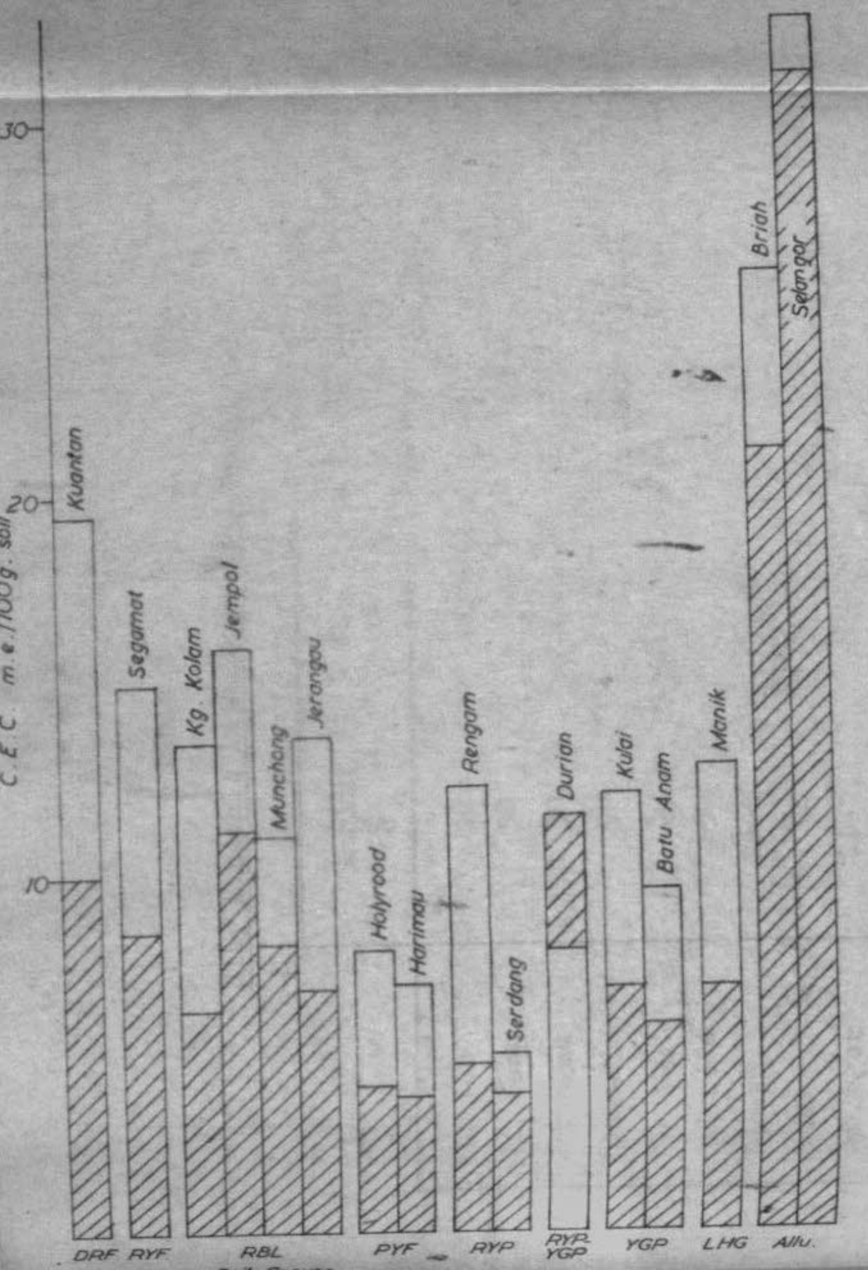

FIG: 3(b) % BASE SATURATION.

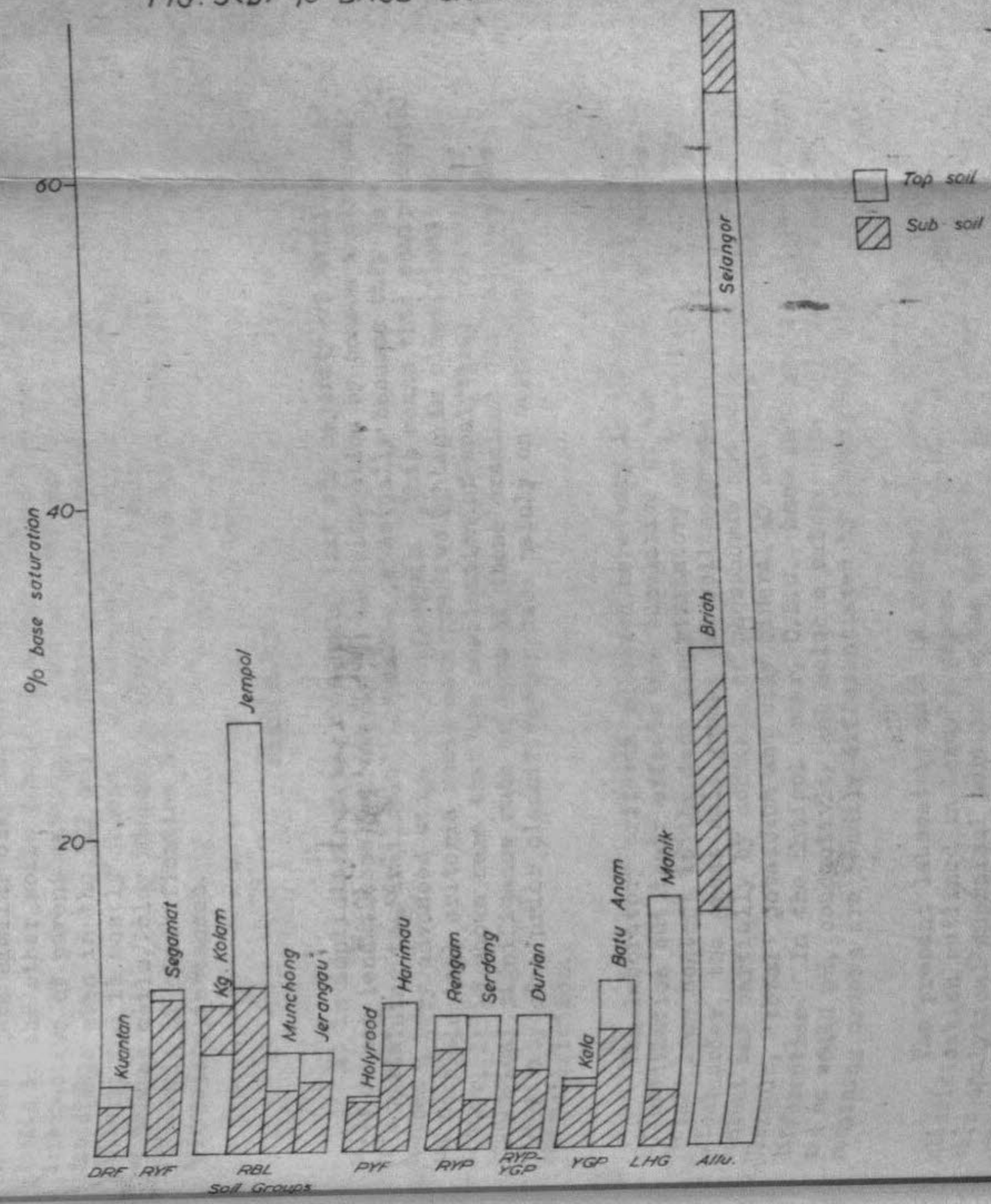

Table 2

Clay Minerals in some Malayan Soils

	Kaolin %	Mica %	Montmorillonite %	Vermiculite %
Kuantan	50	n.d.	n.d.	n.d.
Munchong	50	n.d.	n.d.	n.d.
Jerangau	50	n.d.	n.d.	5
Rengam	50	5	5-10	5-10
Serdang	50	n.d.	n.d.	11-25
Holyrood	50	5	n.d.	5
Durian	26-50	26-50	n.d.	5
Manik	50	5	n.d.	n.d.
Selangor	11-25	11-25	50	n.d.

(n.d. = not detected)

The Selangor (Allu.) and Durian (RYP-YGP) are well segregated and explain their higher potassium contents soluble in hydrochloric acid and C.E.C. of the former. Further data is required to ascertain whether the YGP soils have similar clay suites as the Durian. The preponderance of kaolin in the other soils points to their advanced stage of weathering, irrespective of parent material. Goethite and haematite are only barely detectable even in the DRF and indicates that iron oxides are amorphous. Gibbsite too is mostly absent. In view of the highly leached condition of Malayan soils, clay mineral analysis is unlikely to be effective at low levels of classification but it can deliver conclusive evidence at appropriate instances.

Discussion

It is implicit from the foregoing that the majority of Malayan soils do not lend themselves easily to classification by common analytical data pertaining to 'available' nutrients principally because they have reached a very advanced stage of pedogenesis. This means that environmental and morphological criteria would have great weightage in classification. However, it is shown here that the combination of analytical criteria of pedological significance such as some of those examined can increase the objectivity of a prior classification base mainly on morphological characteristics.

The laboratory criteria assessed here vary in their efficacy of differentiation but their effects are cumulative of the five differentia, 'total' iron content is the most discriminatory on the whole. Within the Oxisol order, the great soil groups are well segregated by total iron content and partially by contents of phosphorus and chromium. In the Ultisols, 'total' potassium and clay mineralogy are quite effective differentiae. In the Entisol Order, C.E.C., base saturation are operative and so would pH, conductivity and soluble salts. The soil groups in the remaining orders are readily differentiated by laboratory data.

The present laboratory data in general support the scheme of classification outlined in Leamy's paper. The main points arising from this analytical appraisal pertain to the validity of certain families and great soil groups in some great soil groups and orders respectively, the distinction between Oxisols and Ultisols, and the nomenclature for great soil groups used by Dudal and Moorman (1964).

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A major conclusion is that the Harimau (PYF), according to its properties should go into the RYP group by defination of the latter. The PYF group should be dropped as the soils do not quite fit in with the oth and Holyrood can be tentatively grouped in the grey podzolic group. Rasa can be accommodated in the RYP. In the RBL group, Jempol and Kg. Kolam might form an intergrade group between RBL and RYP.

Haantjens (1965) has proposed a relaxation of the rather stringent criteria for an oxic horizon in the 7th Approximation. While this proposa is generally welcome, Haantjens has completely omitted the condition on th ratio of free sesquionides to 1:1 minerals to be 1:8 or less in the clay. This condition, in my opinion, is an important criterion and should be preserved although the ratio may be slightly modified if it is found to debar soils with all the other characteristics of Oxisols.

The nomenclature of Dudal and Moorman and adopted by FAO certainly need revision. Terms like 'lateritic' which has common connotation, shoul be avoided if hardened, iron-rich materials are not present. Similarly, pale yellow ferralsols are self-contradictory because they do not actually possess the amount of iron oxides which the name implies. This rather loo usage of terminology leads to much confusion. Why name it a History Club when it is meant for bridge players? In the light of these, the nomenclat of the 7th. Approximation offers an objective way out. Undoubtedly, petra conveys deeper meaning than Ferruginous tropical soils.

In conclusion, it can be stated that laboratory data can play a contributory role in the classification of Malayan and other tropical soil The need for more data including those or physical properties is warranted although existing data have yielded a very satisfactory appraisal.

REFERENCES

DUDAL R. and MOORMAN, F.R. 1964 — Major Soils of South East Asia J. Trop. Geogr. 18, 54.

HAANTJENS, H.A. 1965 — The Classification of Oxisols (Latosols). Technical Memo. 65/5, CSIRO Division of Land Research and Regional Survey, Canberra.

LEAMY, M.L. 1966 — Soil Classification in Malaya (Unpublished) Department of Agriculture, States of Malaya.

SOIL SURVEY STAFF 1960 and AMENDMENT 1964 — Soil Classification: A Comprehensive System, 7th Approximatio Soil Conservation Service, U.S.A.O.

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DISCUSSION

Bailey: - The importance of total elemental analysis should be emphasised. In Sarawak we have been using "total" iron and aluminium oxide analysis for the past 2 years as an aid to classification. The soil is ignited for 30 mins. at 800°C to break clay minerals and then digested with hot concentrated HCl for 30 mins. The method is rapid and accurate enough to be of practical use.

Shao: - I do not think that it is possible to extract total P by 6N HCl. Phosphate extractable by 6N HCl would be a more adequate term for your purpose.

Ng: - "6N HCl soluble" P would definitely be a better term than "total" P.

Shao: - Is 6N HCl capable of extracting all the iron content from the soil? At what temperatures were these soil samples ignited, and the duration of ignition? It is considered advisable to ignite the soil at temperatures above 700°C for say one hour though ½ hr. would probably be sufficient to break the clay lattice properly before extraction for total Fe. The use of sodium dithionite for the extraction of free iron oxide (Claridge, New Zealand) would be worthwhile looking into. The amount of iron extractable by this method as compared with the total iron content in the soil would be useful.

Ng: - The samples were ignited 350 - 400°C for 1 hour. I use a much longer period of extraction viz. 8 hours and as I do not suspect very much iron to be tied up in our clays, 6N HCl would be sufficient to extract most of the iron. The results obtained compare well with those of the Geological Survey where a total fusion with HF Perchloric is used. It is intended in future to include free iron oxide determination for classification purposes.

Andriesse: - Do you suggest to insert in the definition of oxic horizon sesquioxide content or total iron content?

Ng: - Until we have more data we are not justified in using total iron content as a criteria for the oxic horizon.

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GENERAL DISCUSSION ON SOIL CLASSIFICATION

Andriesse: - What is the difference between a strong textural contrast and an argillic horizon?

Leamy: - In an argillic horizon the increase in clay content can take place over 12 inches whereas an abrupt textural change must take place over 3 inches.

Law: - Does the term "Ferralsol" replace 'Latosol' completely?

Leamy: - Yes.

Bailey: - High sulphate soils occur among the Saline Gley Soils in Sarawak but these soils are not necessarily very acid because they may be influenced by the presence of iron in the soil or saline ground water. Acid Sulphate Soils are difficult to classify in Sarawak because the yellow basic ferric sulphate only forms after oxidation of the complex polysulphides.

Thomas: - In Sabah the term "Acid Sulphate" is difficult to use because only on reclamation of Saline clays is there due depression of the pH or influence of sulphur in the profile. In addition these Soils are of very minor extent, occupying probably less than 3,000 acres.

Panton: - In Malaya the Acid Sulphate Soils are seldom saline and are older than the saline gley soils.

Andriesse: - Using 7th Approx. terminology both the saline gley and Acid Sulphate Soils would be in the Hydroquent. At what level is the split to be made then?

Leamy: - There is no provision in the 7th Approximation as yet, so that we have to make the decision ourselves.

Andriesse: - Why are Low Humic Gley soils placed in the Ultisols?

Leamy: - Low Humic Gley soils have an argillic horizon and do not occur on recent alluvium.

Smallwood: - The term "soil variant", I feel at this time could be considered on the same status as a "series" as the number of variants is increasing and problems are arising as to how to place these in the overall classification picture.

Leamy: - The variant is only a mapping device to prevent undue proliferation of series names. I agree that many of our variants have attained series status and will need to be recognised as such soon.

Ives: - Could the Sabah Delegate define a little more clearly the Red-Brown Latosols and Red-Brown Ferralsols?

Thomas: - Ferralsols in Sabah are restricted to Fe rich well structured soils, which show almost no horizonation. The use of the term Latosols is tentatively retained to include the remaining soils as defined by the World Soil Resources paper (1964) covering the Ferralsols.

Ives: - Would Mr. Leamy comment on the apparent similarities, except for Fe content, of the Dark-Red Ferralsols, and the Red Yellow Ferralsols - and is there any possibility that these two may be combined into one Great World Soil Group?

Leamy: - There is an Fe difference between DRF and RYF but both are much higher than all other soils and therefore Fe is not perhaps a very significant criterion for separation.

The correlation:

Malaya	Sabah
RBLS	RY Latosols
Acrox suborder	Red Brown Ferralsols

seems valid.

There is enough justification on profile morphology to keep RYF and DRF apart at Great Soil Group level or perhaps Sub-Group level. There is more indication of an incipient argillic horizon in the RYF than in DRF.

Wong: - How has the arbitrary division of 20 inches from the base of the O horizon been arrived at for classification of Sarawak soils and does this division have any special significance?

Scott: - 20" is a useful division to take as we hope to fit our classification into that of the 7th Approx. It has no special agricultural significance, there being few agronomic data available for Sarawak.

Law: - Does the term "podzolic" refer to the process of podzolisation or to the profile characteristics?

Scott: - In Sarawak a Red-Yellow Podzolic soil can be envisaged to develop into a Grey-White Podzolic through leaching and removal of iron but whether this will eventually develop into a podzol we are doubtful.

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Andriesse: - I believe that Podzolic and podzol processes are different. I have never found podzols developed on heavy textured materials but I have found podzols on sandy textured materials.

Ng: - If terminology implies processes, it assumes that we know a lot about the soil processes. Should we classify soils or soil processes? Surely, when we are more vague on soil processes than on morphology, a descriptive rather than a "process" connotation would be more precise.

Scott: - You can surely recognise that a podzol is the result of a particular process without knowing exactly how the podzol is formed.

Leamy: - Can you say that the podzolic process is similar to or quite different from a podzol process? I think the same process can work on different textured materials for I have seen a podzol developed on clay textured material.

Andriesse: - But this will be in a temperate climate. Under such circumstances climate is more important than material in the pedogenetic processes but this does not apply in the tropics as far as the formation of podzols is concerned.

Thomas: - White clay, humus, iron podzols have been observed in the Interior Plains of Sabah at an elevation of 500 ft. Does Mr. Andriesse suggest that these are in fact polygenetic soils?

Andriesse: - I would be extremely careful to assume they are true podzols unless I have sufficient evidence. In general we do not make the point of classifying soils on what we think the genetic processes are but we classify morphology, bearing in mind that the morphology reflects a certain soil forming process.

Leamy: - In other words at any stage where there is doubt between morphology and process you would prefer morphology so that strictly speaking the terms are mainly descriptive. I feel that it is dangerous at this stage to infer processes at Great Soil Group level. It would be better to bring this factor in at the Order level. In this respect the 7th Approx. approach is more rational.

Andriesse: - With reference to your ferruginous tropical soils, if you find an iron concretion layer in one of your Red-Yellow Podzolics, as this can happen in any oxisol, what would you call it.

Leamy: - In Malaya if a soil has within 3 feet of the surface a ferruginous layer more than 2 feet thick, it would be classed as a Ferruginous Tropical Soil.

Andriesse: - Will the ferruginous layer always qualify for an oxic horizon even though it may not always occur in the position of the B horizon? In Sarawak a soil with this layer is placed in the Red-Yellow Podzolics in the order Ultisols.

Leamy: - The ferruginous layer does not always occur in the position of the B horizon. This is a common feature of some of our Yellow-Grey Podzolics but it does not seem to be a distinct enough feature of the profile morphology to classify the soil as an Oxisol. This is where we can get together to agree on a definition of the ferruginous layer that suits our conditions. There seems to be a close correlation between the Grey White Podzolics of Sarawak and the Yellow Grey Podzolics of Malaya. Is there any major discrepancy between them?

Scott: - There will not be any serious discrepancy if you limit your Yellow-Grey Podzolics as far as colour is concerned to something comparable with those of our Grey-White Podzolics, thus throwing out the soils derived from acid igneous rocks.

Bailey: - It would be better to give the ranges of sesquioxide values used to define the Ferralsols rather than the terms, high or moderately high.

Leamy: - We are now in a position to lend some precision (as far as Fe_2O_3 is concerned) to the sub-division of Ferralsols as having high, mod. high and low sesquioxide content.

Ives: - Basically the tendency in Sarawak is to identify the soils and then interpret the environmental factors associated with each Family so eventual extrapolations may be made - consequently it is possible to find slightly different environments giving rise to the same family through different parts of Sarawak!

Scott: - While we can classify on morphology precisely it is better not to extend the classification criteria to include diagnostic environmental features which are less precise. Otherwise unnecessary anomalies are likely to occur.

Chairman: - From the interesting discussion during the session, it seems advisable to form a sub-committee on soil classification comprising a member from each respective state.

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Session B. - Soil Genesis

Chairman: J. P. Andriesse.

(1) "Factors Involved in the Genesis of Some Shale Derived Soils in Malaya"
by Law Wei Min and M.L. Leamy.

(2) "A Weathering Sequence on Malayan Soils Derived from Basic Effusive Rocks"
by D.W. Ives.

FACTORS INVOLVED IN THE GENESIS OF SOME SHALE-DERIVED SOILS IN MALAYA

LAW WEI MIN

and

M.L. LEAMY

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Abstract

The differences observed among sedentary soils formed on shale seem to reflect more than the known lithological variations in the parent rock. A number of soils developed on shales are described. A distinction is made between the parent rock and the parent material of the soil. Taking the Durian Series as a central concept, an attempt is made to evaluate the relationship between the soils described and to assess their trend of development. A tentative explanation of soil differences is suggested, based on variations in parent material, age and drainage. These variations probably reflect a complex erosional history.

These views have resulted from observations in the field and are based mainly on the morphology of the soils. Free use has been made of the records of the Soil Science Division, Division of Agriculture, States of Malaya, and of the results of discussions with colleagues. Some points are very tentative because of a lack of analytical data.

Introduction

The features and properties of most sedentary soils in Malaya are related remarkably closely to the nature of the parent rock. However a very wide range of soils occurs on argillaceous sediments of Carboniferous and Triassic age, and there does not seem to be a great enough lithological difference between these shales to account for the soil variations observed. Recently attention has been directed to the characteristics of the parent materials derived from shale, as distinct from the parent rock.

The Shales in question are mainly Carboniferous or Triassic in age. Soils formed on the Lower Palaeozoic shales in Pulau Langkawi and on the coal bearing shales of the Miocene are not being considered here. Although the shales are of two ages, there are apparently no great differences in lithology which consistently distinguish one group from the other. However, published lithological data are not comprehensive.

The textural range of the shales is very narrow and falls within the clay size range, although siliceous, silty and even sandy shales of minor extent are also encountered. The shales normally occur interbedded with arenaceous sediments and vein quartz commonly intrudes into these formations.

The colour range is very wide from very pale grey through browns to red and dark red, while the carbonaceous shales are normally dark grey. It is very uncommon to find shale of any one colour occurring to any appreciable extent, and the common situation is to find interbedded shales of different colours.

Description of the soils

The general characteristics of the soils are set out in Table 1, and the following is a brief outline of the diagnostic features of each of the Series:

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Apek Series

A pale coloured soil with weak subangular blocky or weak coarse prismatic structure in the subsoil. The subsoil and the mottled parent material are rather compact. Clayskin development is patchy.

Batu Anam Series

The soil is generally yellow in colour, with firm to very firm consistence and moderate medium and coarse subangular blocky or prismatic structure in the subsoil. Both the subsoil and the parent material are variegated yellow and red with light grey streaks. Light grey is dominant at depth. Clayskins are discontinuous to almost continuous. A nodular laterite band less than six inches thick is quite common in the B horizon.

Durian Series

This soil is deeper and generally darker coloured than the Batu Anam Series. Nodular laterite or laterized shale fragments, forming a band about six inches thick at the base of the B horizon, may be present. The subsoil is firm to very firm and moderately compact with moderate medium subangular blocky structure that tends to be prismatic. The parent material is variegated red and yellow with light grey streaks, and grey colours become dominant at depth. Clayskin development is discontinuous.

Tavy Series

This soil consists of two feet or more of laterite-free soil overlying nodular laterite less than three feet thick. The soil is friable with a weak medium subangular blocky structure. The parent material is variegated brownish yellow and yellowish red, with a generally paler colour at depth.

Malacca Series

This soil has generally less than two feet of soil above the laterite band which is more than three feet thick. Laterite is normally nodular in the upper parts and becomes more massive with depth, though laterite boulders commonly litter the surface. The parent material is strongly variegated yellowish red, pale yellow and light grey, with yellowish red less dominant at depth.

Munchong Series

This is a friable, deep soil generally more than four feet thick. The subsoil has moderate medium subangular blocky structure with patchy to discontinuous clayskins. Laterite is normally absent although it may occur deeper than four feet. The parent material is yellowish red to reddish yellow with faint light grey patches.

Soil Forming Factors

1. Parent material

Parent material has been defined as "the material that is not modified by any pedogenic process, or as fresh regolith" (Nikiforoff, 1949). This is in fact the weathering mantle of the parent rock. Because the processes of soil formation and weathering operate simultaneously in the same medium and continuously overlap and effect each other, the true parent material of the soil no longer exists in an unmodified condition.

Up till now the term "parent material" has been used rather loosely in Malaya and has included both parent material and parent rock. It is suggested here that the distinction is very real and should be emphasised. It is true that the parent rock has left some of its influences on the

Series	Parent Rock	Terrain	Topsoil (Ah) Colour	Texture	Consistence	Structure	Thickness	Subsurface Horizon (Ae/AB) Colour	Texture	Consistence	Structure	Mottles
Apek	Shale	C_2-C_3	10YR5/1	sl	mfr	1fcr	2 in.	10YR 7/1	sl	mfi	1fsbk	1/f 7.5YR7/ 7.5YR7/
Batu Anam	Shale	C_2	10YR5/2	sic - c	mfr	1-2 fsbk	2 in.	2.5Y7/4	sicl - c	mfr	1fmsbk	Sometime
Durian	Shale	C_3-C_4	10YR3/3	fscl	mfr	1-2fsbk	3 in.	10YR5-6/6	sicl - c	mfi	1-2fmsbk	1/1 light re
Tavy	Shale	C_2 C_2-C_4	7.5YR4/4	scl	mfr	1mgr-1fsbk	3 in.	10YR5/8	scl	mfr	1fmsbk	-
Malacca	Shale	C_1-C_3	10YR4/2	cl	mfr	2fsbk	1 in.	10YR5-6/8	sic - c	mfr	2fmsbk	-
Munchong	Shale	C_2-C_3	10YR4/4	fsl - sil	mfr	2fcr	4 in.	7.5YR5/6	sicl	mfr	2msbk	-

N.B. The abbreviation are as outlined in Leamy & Panton (1966). with the following additions :-

Variegation .

Weakly variega

Moderately va

Strongly varie

As far as the time factor is concerned, the geological age of the parent rock does not seem to have any influence on the soil at all, as the same series is found to occur on shales of Carboniferous as well as Triassic age. Rather, it is the pedological age that is important and this is closely linked to the geomorphology of the site, since little of the earth's topography is older than Tertiary and most of it no older than Pleistocene (Thornbury, 1954 and Nikiforoff, 1949). Nikiforoff (1949) considered that the soils that exist at present, with so-called "permanent" characteristics do so under a set of conditions, and that if anyone of these conditions changes, there are corresponding changes in the characteristics of the soil. Since geomorphological features are a function of erosion, we have to consider normal erosion as a factor of soil profile development (Milne, 1936). Although the soils under discussion tend to occur within certain terrain classes, overlapping does occur. With these sedentary soils, any changes affecting the removal of part or whole of the A horizon, will start afresh the effects of the soil forming factors. This results in the sinking of the A horizon with subsequent encroachment into the B horizon and the sinking of the B deeper into the C horizon. The main result of the evolution of such sedentary soils is that the A horizon of the present soil may not consist of the same material as the A horizon of the Carboniferous or Triassic. The infringement of each horizon upon the other may be so gradual as to involve no changes in the general characteristics of the whole profile. On the other hand, the movement on sloping terrain may be rapid enough to produce marked morphological features such as stone lines, with textural, consistence and even colour differences above and below; and A horizon clay-skins which are possibly relict from a former B horizon.

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TABLE 1: SUMMARY OF SOIL CHARACTERISTICS

Series	Parent Rock	Terrain	Topsoil (Ah) Colour	Topsoil (Ah) Texture	Topsoil (Ah) Consistence	Topsoil (Ah) Structure	Topsoil (Ah) Thickness
Apek	Shale	C_2-C_3	10YR5/1	sl	mfr	1fcr	2 in.
Batu Anam	Shale	C_2	10YR5/2	sic-c	mfr	1-2 fsbk	2 in.
Durian	Shale	C_3-C_4	10YR3/3	fscl	mfr	1-2fsbk	3 in.
Tavy	Shale	C_2 C_2-C_4	7.5YR4/4	scl	mfr	1mgr-1fsbk	3 in.
Malacca	Shale	C_1-C_3	10YR4/2	cl	mfr	2fsbk	1 in.
Munchong	Shale	C_2-C_3	10YR4/4	fsl-sil	mfr	2fcr	4 in.

Series	Subsurface Horizon (Ae/AB) Colour	Texture	Consistence	Structure	Mottles	Clay-skin	Thickness
Apek	10YR 7/1	sl	mfi	1fsbk	f1f 7.5YR7/8 7.5YR7/0		6"
Batu Anam	2.5Y7/4	sicl-c	mfr	1fmsbk	Sometimes	1C	6-12"
Durian	10YR5-6/6	sicl-c	mfi	1-2fmsbk	f1f light red	1C	6-12"
Tavy	10YR5/8	scl	mfr	1fmsbk	-	1C	6-18"
Malacca	10YR5-6/8	sic-c	mfr	2fmsbk	-	1C	24"
Munchong	7.5YR5/6	sicl	mfr	2msbk	-	-	12"

Series	Subsoil (B) Colour	Texture	Consistence	Structure	Compaction	Mottles/Variegation	Clay-skin	Thickness
Apek	2.5Y7/2	sc	mvfi	1vcpr	1-2	m2p red. yell.	1-2C	24"
Batu Anam	10YR7/4-6 7.5YR6/6 2.5YR5/8	c	mfi	2cpr & 1-2fmsbk	1	2V	2-3C	12-24"
Durian	10YR6/6 7.5YR5/6	c	mfi-mvfi	2cpr & 1-2msbk	1	m1-2d 5YR5/8	2C	12-36"
Tavy	5YR5/8	sc-c	mfi	1msbk	0-1	-	2C	12-36"
Malacca	10YR6/6 7.5YR6/6	sic-c	mfr	1msbk	1-2	f1f 7.5YR6/8	2-3C	36"
Munchong	7.5YR5/6	sicl-sic	mfr	2msbk	0	-	2C	24-48"

Series	Parent Material (C) Colour	Texture	Consistence	Structure	Compaction	Mottles/Variegation	Clay-skin	Thickness	Laterite Type	Cementation Compaction	Thickness	Depth from surface	Horizonation
Apek	10YR7/1	sic	mvfi	m	2	f2d 10YR7/8 7.5YR6/0	1C	12-24"	Nodular	w & 0-1	6 in.	in B	Ah/Ae/Bt/Cu
Batu Anam	10YR8/2-3 2.5YR5/6-8	c	mvfi	1fsbk-m	2-3	2V	1-2C	24" in	Nodular	w & 0-1	6 in	in B	Ah/Ae/Bt/Cu or Cm
Durian	10YR8/4 2.5YR4/8	c	mfi	1cpr-m	2	2V	1C	12-36"	Nodular and Laterised pm	w & 0-1	6 in.	Base of B	Ah/AB/Bt/Cu or Cm
Tavy	5YR5/8	sic-c	mfr	m	2	1V	-		Nodular	w & 0-1	24"	16-40"	Ah/Ae/Bcn/Cu
Malacca	5YR5/8 10YR7/1	c	mfr	1msbk	1	2V	1C		Massive & nodular	s & 0-1	36"	< 24"	Ah/Ae/Bcn/Cm
Munchong	7.5YR5/6 5YR5/8	sic	mfi	1msbk	0-1	1V	1C	24-36	Nodular	w & 0	6"	below 48"	Ah/Aej/Btj/Cm

N.B. The abbreviation are as outlined in Leamy & Panton (1966), with the following additions :-

<u>Variegation</u>

Weakly variegated 1V
Moderately variegated ... 2V
Strongly variegated 3V

<u>Compaction</u>

Not compacted 0
Weakly compacted 1
Moderately compacted 2
Strongly compacted 3

<u>Cementation</u>

Weakly cemented .... w
Strongly cemented ... s
Indurated i

developed soil, mainly reflected in texture and nutrient status on a comparative basis, but under present climatic conditions the soil formed on any parent rock is far removed in nature from it. Normally different parent rocks will weather to give different parent materials thereby forming different soils, but it should be noted that one parent rock, owing to differences in the site conditions, may weather to form more than one kind of parent material, thus giving rise to more than one soil. In the case of the shale-derived soils under discussion, it is suggested that demonstrable differences in the parent material, such as for instance the degree of variegation and the consistence (Table 1), are associated with soil differences, whereas co-variant differences in the parent rock are not clearly evident.

One diagnostic feature of the parent materials formed from the shales is the highly mottled or variegated appearance, where a mixture of two or more colours is so complex that it is very difficult to select one dominant colour as the matrix. A combination of yellowish red or reddish yellow with pale brown or light grey is very common. The variegation may be strong where the contrasting colours are very prominent, or weak where the colours merge into one another. This material resembles the "mottled" zone associated with laterite formation, and in places grades downwards into almost uniformly pale coloured clay, which may represent the "pallid" zone (Walther, 1915). The texture of the parent material is normally a silty clay or clay, and the consistence ranges from friable to very firm. The occurrence of two horizons within the parent material is quite common - an upper horizon free of parent rock, overlying a horizon containing pieces of the parent rock. Sometimes the upper horizon is absent.

2. Other soil forming factors

Parent material in the broad sense, i.e. including parent rock, has always been given pride of place as a soil forming factor in Malaya, while climate, relief, vegetation and time have been relegated to secondary positions.

Climate is quite uniform except for variations in seasonal rainfall in some parts of Malaya. The natural vegetation tends to reflect the nutrient status of the soils, with poorer stands occurring on soils of comparatively lower nutrient status.

As far as the time factor is concerned, the geological age of the parent rock does not seem to have any influence on the soil at all, as the same series is found to occur on shales of Carboniferous as well as Triassic age. Rather, it is the pedological age that is important and this is closely linked to the geomorphology of the site, since little of the earth's topography is older than Tertiary and most of it no older than Pleistocene (Thornbury, 1954 and Nikiforoff, 1949). Nikiforoff (1949) considered that the soils that exist at present, with so-called "permanent" characteristics do so under a set of conditions, and that if anyone of these conditions changes, there are corresponding changes in the characteristics of the soil. Since geomorphological features are a function of erosion, we have to consider normal erosion as a factor of soil profile development (Milne, 1936). Although the soils under discussion tend to occur within certain terrain classes, overlapping does occur. With these sedentary soils, any changes affecting the removal of part or whole of the A horizon, will start afresh the effects of the soil forming factors. This results in the sinking of the A horizon with subsequent encroachment into the B horizon and the sinking of the B deeper into the C horizon. The main result of the evolution of such sedentary soils is that the A horizon of the present soil may not consist of the same material as the A horizon of the Carboniferous or Triassic. The infringement of each horizon upon the other may be so gradual as to involve no changes in the general characteristics of the whole profile. On the other hand, the movement on sloping terrain may be rapid enough to produce marked morphological features such as stone lines, with textural, consistence and even colour differences above and below; and A horizon clay-skins which are possibly relict from a former B horizon.

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Genesis of the soils

Because Durian Series has morphological features which in many respects seem intermediate between several of the other series and because it is of widespread occurrence, it is regarded for convenionce as the centr concept and the inter-relationship of the shale soils described previously is discussed under three headings as follows:

(a) The Malacca - Tavy - Durian - Batu Anam sequence

The discussion of this sequence is centred mainly on the genesis of laterite on one hand, and normal erosion as a factor of soil formation on the other.

Durian and Batu Anam soils commonly have a band of laterite nodules (in some cases laterized shale fragments) less than six inches thick occurri frequently in, or at the base of the B horizon and usually mixed with a stone line of angular quartz. The laterite in the Tavy is nodular, less than three feet thick, and weakly cemented and compacted. The laterite in the upper par is generally more rounded and finer in size than that lower down. Malacca has more than three feet of laterite which may be nodular, though commonly massive with big boulders littering the surface. Generally the upper portion of the laterite tends to be nodular more rounded and finer in size, while th lower portion is more massive and compacted.

In the Sungei Tekal and Bee Yong Estates near Kerdau, north-west of Temerloh, the Malacca series occurs on rolling to hilly terrain and occupies higher levels and upper slopes while Durian soils tend to occur on the lower levels and lower slopes. Batu Anam series is found on flatter terrain further west and south of the area.

Wagner (pers. comm.) has observed some Malacca soils on the tops of a generally rolling, to hilly and steep terrain in the Jerantut area and in the vicinity of Kuala Lipis. Both areas are moderately dissected peneplains, with Malacca soils on the tops and upper slopes, and Durian soils on the lower slopes. Batu Anam soils tend to occur on elevations lower than the Durian and Malacca in the Jerantut area, but they have not yet been observed in the Kuala Lipis region. Dumanski (pers. comm.) has also found Malacca soil occuring on hilly terrain at higher elevations than the generally flatter surrounding area.

Tavy soils, where they occur in this sequence, tend to occupy positions in the landscape between Malacca and Durian soils.

These observations seem to suggest that the laterite has been formed in an earlier period and is now undergoing degradation, with the Tavy, Durian and Batu Anam soils developing on the younger surfaces formed as a result of the dissection. Such relic or "dead" laterite has been reported from many parts of the world (Sivarajasingham et al. 1962 p. 20).

Laterite is present in most sedentary soils in various forms and amounts and Panton (1956 pp. 419 - 20) has concluded from observing its ubiquity that "laterite formation is at present taking place in Malaya under a variety of topographical positions, and one of the most remarkable features is the absence of residual or fossil laterite occurrences". Some of the differences in the amount of laterite observed in the shale soils under discussion (and specifically in Malacca - Tavy - Durian soils) may be direct related to differences in the age of the soils. However, the possibility cannot be excluded that this sequence has resulted from the destruction of a massive laterite cap and the migration of laterite debris downslope, and the marked differences in the form of the laterite in different soils, and the occurrence in many places of laterite caps on hill tops suggest that fossil laterite may, in fact, be preserved in some places.

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From the above observations it is suggested here that there are present in Malaya laterites of two ages - a laterite formed on an old, subsequently dissected surface, and which is now undergoing degradation; and a younger laterite that is now being formed under present day conditions.

Panton (1956, p. 420) considered that among the influencing factors in laterite formation" .... the nature of the parent material of primary importance. The higher the iron content of the original rock the more likely is the formation of a well-marked laterite horizon in the derived soils ...." He also emphasised the importance of the interaction between parent material and the other laterite forming factors. However, laterite formation is not likely to be confined to iron-rich parent rocks, because as Sivarajasingham et al. (1962, p 45) emphasise laterite may be formed by enrichment from outside sources and there are in fact "some cases in which low iron content of the original rock would be expected to make enrichment essential." It does not therefore seem likely that the differences in the amount of laterite in the soils described are governed only by variation in the iron content of the parent rock, particularly as such variation has not been conclusively demonstrated.

It does not yet seem to be established beyond question that the Malayan climate is suitable for laterite formation. Although laterite formation is very marked in Malacca and Singapore under a fairly uniformly distributed rainfall (Panton, 1956), and although Scrivenor (1909) disputed the contention that a well-marked alternation of wet and dry seasons are necessary, the bulk of opinion in the literature favours and alternation of wet and dry conditions (Sivarajasingham et al. 1962 p. 14) Table 3 shows the mean rainfall figures over a certain period for localities where laterite is known to occur. It should be mentioned here that the conclusions of Scrivenor (1909) and Panton (1956) that the prevailing hot, wet and humid climate of Malaya must be acknowledged to be suitable for laterite formation, appear to be based mainly on the assumption that all the laterite observed is currently being formed. Although no conclusive evidence to the contrary is offered in this present paper, the material put forward does at least raise a reasonable doubt as to the absence of fossil laterite, and if this doubt were to be confirmed by future work, these published conclusions regarding climatic suitability may no longer be tenable. However, the microclimate within the soil may be as important in this respect as the general climate, and many Malayan soils are subject to alternating wet and dry conditions.

With regard to the laterite which is found on rolling to hilly terrain, particularly on upper slopes and hill tops, the following hypothesis is offered:

Malacca Series, with strong laterite development, was formed on the undulating terrain of a peneplain. The geomorphic cycle was rejuvenated by uplift, or by a lowering of base level, and dissection of the peneplain surface commenced. Dissection was probably accompanied by the migration of laterite fragments downslope, where Tavy soils now commonly occur, and such a process may well account for the present day ubiquity of fragmental laterite in sedentary soils. As a result of deepening dissection the mottled and pallid zones underlying the laterite were possibly exposed on lower slopes, and this material became the parent material of Durian, Batu Anam and possibly Apek soils.

On the other hand the prevalent high rainfall combined with the heavy texture parent material of some shale soils suggests that a fluctuating water table could be playing an important part in present day laterite formation in suitable landscape situations. However, such situations would account for only a small proportion of the laterite observed throughout Malaya.

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(b) The Durian - Batu Anam - Apek Sequence

The prevailing view is that the Batu Anam and Apek soils have developed from light coloured shales of low iron content (e.g. Null, Acton & Wong 1965, p.21. There is a decrease in the total ferric oxide extracted with concentrated hydrochloric acid from the Durian series to the Apek series (Table 2). The lower content of ferric oxide in the Apek is also reflected in the mottled nature of the parent material as compared to the varigated parent material of the Batu Anam and Durian.

The variegated zones of the Batu Anam and Durian are very similar. Although there are instances of Batu Anam overlying light coloured shales, these shales do not occur to any appreciable extent. Interbedding of light and dark coloured shales is more the general rule, and these weather to a variegated clay which is the parent material of Durian and Batu Anam.

Apek and Batu Anam soils are found on undulating terrain which could be classified in the late mature or early old age stage of the geomorphic cycle. On the other hand Durian soils most commonly occur on rolling to hilly terrain which could represent late youth or early maturity.

The subsoils of Apek and Batu Anam are more compacted and firmer than that of Durian. Together with the high seasonal rainfall and relatively slow draining sites, this may have resulted in intermittent gleying due to a perched water table in the Apek and Batu Anam. No true gley horizon has been encountered in the field, except in depressions. Intermittent gleying and the prismatic structure in the subsoil may have resulted in a lower ferric oxide content of the Apek and Batu Anam.

These three soils from a drainage sequence on hilly, rolling and undulating terrain, but it does seem that the properties associated with drainage have been influenced by some other factor, because sedentary soils formed on other parent rocks, and even other soils formed on shale do not exhibit such a sequence on similar terrain. It is suggested here that the compact, clayey nature of the strongly weathered parent material, combined with the geomorphic history and the age of the site has produced this sequence. The mottled or variegated clay common to the C horizons of the three soils is probably relict, in some degree, from a former cycle of intense weathering, while other profile properties reflect difference in the age and drainage of the site.

(c) The Durian-Munchong sequence

As has been mentioned Durian soils are commonly found on rolling to hilly terrain, but Munchong soils are more common on undulating to rolling land. Munchong is a deeper, more uniform soil than Durian, with a more friable consistence and a better internal drainage. These properties may in part be due to the ferric oxide content which is generally about 8% in Munchong and below 5% in Durian (Table 2).

This sequence may be more apparent than real, because there is some evidence to suggest that Munchong soils are associated with a complex interbedding of arenaceous and argillaceous rocks. It may be significant that the parent material of Munchong is noticeably less different in nature from the parent rock, than is the case with Durian, and it may in fact be formed in locations where dissection has removed most traces of previous weathering.

Classification of the soils

The soils under discussion have been classified, mainly on morphological criteria, up to Order level. The Great Soil Groups employed have been

vely defined and the terminology for Suborders and Orders has been
d from the 7th Approximation (Soil Survey Staff, 1960) following the
ions made by Haantjens (1965). Table 4 shows the suggested
ication:

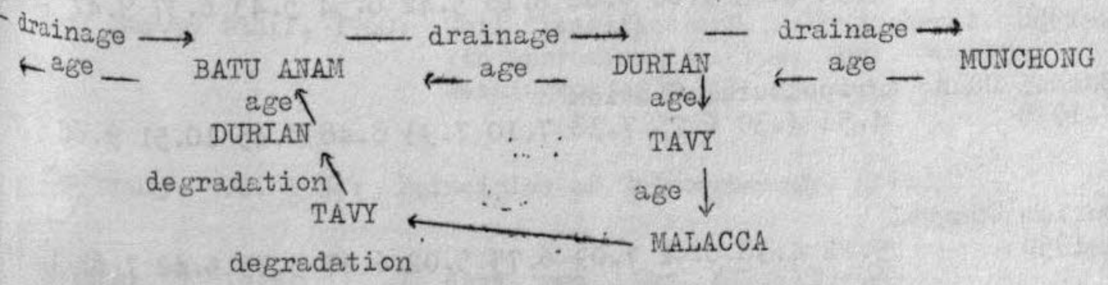
Table 4 Classification of the shale soils

DER	SUBORDER	GREAT SOIL GROUP	FAMILY	SERIES
sol	Argox	Reddish Brown Lateritic	Munchong	Munchong
	Haplox	Ferruginous Tropical Soils	Malacca	Malacca
			Tavy	Tavy
sol	Udult	Intergrade Red Yellow Podzolic - Yellow Grey Podzolic	Durian	Durian
		Yellow Grey Podzolic	Batu Anam	Batu Anam Apex

Conclusions

From a study of the admittedly incomplete evidence put forward it is
ded that, in explaining differences between these shale soils, the
of the parent material should be regarded as equally, if not more
ant than the nature of the parent rock; that the pedological age of
te is more relevant than the geological age of the rock, and that an
tanding of geomorphic processes as expressed through normal erosion
reat assistance. It is also suggested that much of the laterite
ing in Malaya may in fact be fossil laterite.

In an attempt to simplify a complex array of profiles and to
ise common characteristics and possible relationships, the soils have
iscussed in a series of sequences, which are summarised in the
ing diagram:



Differences among these shale-derived soils, which in the past have
ttributed to variations in the parent rock, now seem to be more closely
d to the nature of the parent material, combined with the character-
of the site and its erosional history.

Table 2

Series	Lab. No.		Depth in.	Total Fe_2O_3%
Apek	RP940	T	0 - 7	0.143
		Sa	7 -13	0.144
		Sb	13 -32	0.686
		Sc	32 -52	0.643
Batu Anam	RP946	T	0 - 4	1.42
		Sa	4 -16	1.68
		Sb	16 -24	3.81
		Sc	24- 48	2.50
Batu Anam	RP947	T	0 - 4	0.92
		Sa	4 -12	0.92
		Sb	12 -24	1.14
		Sc	24 -48	3.47
Durian	RP948	T		3.17
		Sa		3.71
		Sb	18 -24	6.28
		Sc	24 -30	4.64
		Sd	30 -40	3.92
		Se	40 -50	2.50
Munchong	RQ580	T	1 - 3	7.29
		Sa	3 -14	8.08
		Sb	14 -30	8.08

Table 3

Mean Monthly Distribution of Rainfall in inches

	J	F	M	A	M	J	J	A	S	O	N
State of Malacca											
a) Alor Gajah 1932-1958	4.95	4.73	9.66	8.04	6.18	5.42	6.54	5.43	6.37	9.47	9.06
b) Sungei Udang Agricultural Station 1932-1958	4.51	4.30	6.25	7.38	7.10	7.93	8.48	8.45	10.51	9.68	9.9
c) Durian Tunggal 1933-1958	5.22	4.38	6.61	7.09	6.75	5.02	6.67	5.75	6.42	7.65	10.0
State of Johore											
Yong Peng	10.28	5.44	9.83	10.06	9.29	5.34	4.84	8.84	5.38	9.47	8.

REFERENCES

Haantjens, H.A. 1965: The classification of Oxisols (Latosols). C.S.I.R.O. Division of Land Research and Regional Survey, Canberra. Tech. Mem. 65/5, 27 pp.

Leamy, M.L. and Panton, W.P. 1966: A Soil Survey Manual for Malayan Conditions, Division of Agriculture Bulletin 119, Ministry of Agriculture and Co-operatives, Kuala Lumpur, Malaya.

Milne, G. 1936: Normal Erosion as a Factor of Soil Profile Development. Nature 138 p. 548.

Nikiforoff, C.C. 1949: Weathering and Soil Evolution. Soil Sci. Vol. 67, 219-230

Null, W.S., Acton, C.J. and Wong, I.F.T. 1965: Reconnaissance Soil Survey of Southern Johore. Malayan Soil Survey Report No.1/1965, Soil Science Division, Division of Agriculture, Kuala Lumpur.

Panton, W.P. 1956: Types of Malayan Laterites and Factors Affecting Their Distribution. Proc. VI[c] Int. Cong. Soil Paris. V, 69, 419-423.

Scrivenor, J.B. 1909: The Use of the Word Laterite. Geol. Mag. / V / 6, 574-575.

Sivarajasingham, S., Alexander, L.T. Cady J.G. and Cline, M.G. 1962: Laterite Advances in Agronomy, 14, 1-60.

Soil Survey Staff, 1960: Soil Classification, A Comprehensive System, 7th Approximation. U.S. Govt. Printing Office, Washington, D.C.

Thornbury, W.O. 1954: Principles of Geomorphology, Wiley.

Walther, J. 1915: Z. devt. geol. Ges. 67B, 113-140.

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DISCUSSION

Young: - Have cases been described in which soils of the series described in this paper occur in a catena?

Law: - In Malaya we have not found the repetitive sequence of topography implicit in the term "catena" as I understand it. Consequently, little attention has been paid to this aspect in mapping.

Leamy: - There is a catenary relationship between these soils but it is not related only to current pedological processes, and therefore is not found intact everywhere. In various parts of the country, various sectors of the catena Malacca/Tavy/Durian/Batu Anam/Apek and even Munchong can be seen. Geomorphic history of the landscape is very important in understanding the distribution of these catena remnants.

Smallwood: - Do you account for the difference between "nodular" and "massive" laterite in the Malacca Series. Is the nodular laterite a breakdown of massive laterite or is it formed separately and how is massive laterite related to nodular laterite in its formation? Have they anything in common, e.g. age?

Leamy: - Nodular laterite can be derived from massive laterite by mechanical disintegration.

Smallwood: - In the nodular laterite a characteristic feature is the concentric layering of the nodules and this is absent in the massive laterite.

Law: - This is a feature which will have to be investigated more thoroughly.

Wong: - If the normal geomorphic cycle is towards peneplanation, would the sequence on page 11 not be the other way round i.e. Apek - Batu Anam - Durain - Munchong with the loss of iron and clay from the 1st 3 soils and accumulation of iron and clay in the Munchong?

Law: - Munchong series appears to be developing on much younger surface than the Malacca - Durian - Batu Anam sequence.

Scott: - In Sarawak some variegated and pallid zones are evident in strongly rolling country in minor patches unrelated to slope or striking deep into the weathering zone and conforming to the bedding planes of the parent rock. I think that in such cases it is difficult to suggest any other reason for these features than differences in the parent rock itself. Where these soils occur on lower more gentle country they are more widespread and commonly associated with erosion surface in such cases they may be partly a response to multiple weathering cycles.

Thomas: - What is the approximate age of the landscape on which the old laterite was formed?

Leamy: - I would propose the following very tentative hypothesis to explain these soils

(a) Peneplanation in Cretaceous
(b) Disruption by granite intrusion
(c) Dissection of the peneplain to give the Malacca/Tavy/Durain/Batu Anam/Apek sequence
(d) Formation of a more recent peneplain surface on which Munchong is developed.

One conclusion would be that conditions favourable to laterite formation pertained during the period of the first peneplain, but not when the second peneplain was forming.

A WEATHERING SEQUENCE ON MALAYSIAN SOILS DERIVED FROM BASIC EFFUSIVE ROCKS

By

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Abstract

The chemistry of some Malaysian soils derived from basic effusive rocks is examined and on this basis the soils are grouped into six weathering groups.

An attempt is made to relate the soils from widely separated areas of Malaysia into uniform weathering sequences.

It is inferred that the physical nature and age of the parent rocks are of major importance, while the nature of the terrain, by comparison appears to have only minor significance in the weathering of the basic rock derived soils of Malaysia.

Introduction

An interest in these soils was aroused after reading a paper by Guha (1964) and then visiting the Semporna Peninsula region during the First Malaysian Soils Conference. Guha (1964) pointed out the apparent similarities between the Kuantan series and the Jarangan sub-family, and this paper is an attempt to extend the interest fostered by Guha to include all soils derived from basic extrusives throughout Malaysia.

The occurrence, nature and existing classifications of these soils, from the different parts of Malaysia (Sabah, Sarawak and Malaya) are discussed. The degree to which each of the soils have been weathered has been assessed by reference to their chemistry. An outline of the statistical method and chemical data utilised is incorporated herein. (Unfortunately, due to a lack of data and non-conformity in analytical method, it was not possible to pursue the phosphate anomaly noted by Guha).

These basic rock derived soils are grouped into six weathering classes, and then, on the basis of morphology, are grouped into weathering sequences. Chemical and morphological data employed are shown in Tables 1 and 2. An attempt is made to substantiate the proposed weathering sequences by reference to the nature and significance of the parent rock and the terrain.

For the purpose of this exercise, two assumptions have been made -

a) that the nature of vegetation growing on the various soils has little differentiating effect on their chemistry and morphology;
b) that the climate is relatively uniform throughout the low-land regions of Malaysia where these soils are found.

Distribution, Nature and Existing Classification of Soils From Basic Effusive Rocks in the Malaysian Region

1. Sabah

Soils developed over rocks of basaltic composition have been described from two regions in Sabah. These are the Semporna Peninsula (Paton 1961) and the Labuk Valley (Hooper and Ives 1964). The soils of these two areas will be considered initially as two separate units as this is the first

TABLE 1

	6″	Series or Sub. Family	
1.	5·9	Kawa	Very Weakly Weathered
2.	3·9	Livodoi	
3.	5·4	Bombalai	
4.	5·3	Besar	Weakly Weathered
5.	6·1	Tiger	
6.	8·7	Baba	
7.		Kobavan	
8.	3·9	Sinaputan	Weakly-Moderately Weathered
9.	4·65	Nerelud	Moderately Weathered
10.	5·45	Mengkadait	
11.	5·0	Quoin	Strongly Moderately Weathered
12.	4·8	Mostyn	
13.	5·0	Table	
14.	4·4	Antayan	Strongly Weathered
15.	5·58	Bilai	
16.	4·8	Tarat	
17.	4·8	Kuantan	
18.	5·0	Pelawan	
19.	4·4	Jerangan	

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SELECTED CHEMICAL DATA FOR SOILS DERIVED FROM BASIC EFFUSIVE ROCKS

TABLE I

	pH (H_2O)				(Ca + Mg)/K ratio				Exchangeable K^+ meq/100 g.				Base Saturation %				C.E.C. meq/100g.				Clay %				Series or Sub. Family	
	6"	12"	24"	36"	6"	12"	24"	36"	6"	12"	24"	36"	6"	12"	24"	36"	6"	12"	24"	36"	6"	12"	24"	36"		
1.	5·9	5·0			89	99			·23	·08			66	34			31·7	24·1			38	44			Kawa	
2.	3·9	3·9	4·45		84·7	71·5	139·0		·11	·14	·16		38	38	56		25·2	27·2	37·6						Livodoi	Very Weakly Weathered
3.	5·4	5·4			545	152			·03	·09			58	56			28·4	26·3			25	28			Bombalai	
4.	5·3	5·3	5·2	5·2	157	157	60	60	·06	·06	·23	·23	65	65	60	60	14·9	14·9	23·8	23·8	33	33	56	56	Besar	
5.	6·1	6·1	6·1	6·1	43·8	43·8	48·9	48·9	·25	·25	·12	·12	58	58	61	61	20·3	20·3	10·1	10·1	18	38	19	19	Tiger	Weakly Weathered
6.	8·7	7·9	6·5	8·3	222·7	309·8	361·0	281·7	·07	·06	·04	·06	77	84	68	83	20·75	22·63	21·65	20·75					Baba	
7.					84·5	139·6	163·75	145·5	·06	·08	08	08	66	62	77	78	21·32	18·48	17·28	17·54					Kobavan	
8.	3·9	4·7	4·8	3·8	41·9	58·2	27·5	14·6	·17	·10	·14	·31	33	27	18	17	21·6	19·5	22·9	29·7					Sinaputan	Weakly-Moderately Weathered
9.	4·65	4·98	4·98	5·05	19·7	39·5	39·5	28·0	·14	·06	·06	·05	21	24	24	13	14·65	10·57	10·57	9·08					Nerelud	Moderately Weathered
10.	5·45	5·48	5·58	5·58	19·2	28·4	49·5	49·5	·06	·05	·06	·06	17	21	43	43	7·45	6·75	7·55	7·55					Mengkadait	
11.	5·0	5·3	5·0	4·9	4·3	2·7	1·0	3·0	·21	·18	·30	·20	11	13	9	11	12·3	10·7	10·1	10·4	79	89	88	89	Quoin	
12.	4·8	4·8	5·0	5·0	26·0	26·0	12·4	12·4	·07	·07	·05		15	15	6		13·7	13·7	12·6		77	77	82	37	Mostyn	Strongly Moderately Weathered
13.	5·0	5·0	5·0	5·2	9·0	1·4	1·4	1·38	·12	·12	·20	·46	11	11	6	10	11·7	11·7	10·8	10·8	76	76	83	78	Table	
14.	4·4	4·4	4·8	5·3	6·25	9·4	8·9	25·0	·12	·08	·05	·03	6	5	3	4	17·2	17·6	19·1	18·7					Antayan	
15.	5·58	5·50	5·18	5·18	32·75	23·0	14·8	14·8	·04	·05	·05	·05	22	20	20	14	6·48	6·66	6·50	6·50					Bilai	
16.	4·8	4·8	5·7	5·7	1·6	1·6	3·4	3·7	·07	·07	·13	·13	2	2	10	11	8·8	8·8	6·8	6·8					Tarat	Strongly Weathered
17.	4·8	4·8	4·7	4·5	2·5	2·5	3·8	3·8	·06	·06	·04	·04	2	2	2	4	13·0	13·0	10·09	6·84	84	84	86	86	Kuantan	
18.	5·0	4·8	4·8	4·8	5·0	4·0	4·0	4·0	·06	·04	·04	·04	3	3	3	2	13·7	10·60	11·63	11·63	76	76	77	77	Pelawan	
19.	4·4	4·6	4·7	4·8	3·6	10·7	6·3	8·5	·05	·03	·04	·02	1	5	6	4	14·2	9·3	8·3	7·9	66	81	82	86	Jerangan	

TABLE 12

PHYSICAL CHARACTERISTICS OF EACH SOIL

NO.	SOIL	A HORIZON COLOUR*	A TEX.	A CONS.	A STRUCTURE	B HORIZON COLOUR*	B TEX.	B CONS.	B STRUCTURE	C HORIZON COLOUR*	C TEX.	C CONS.	C STRUCTURE	STONES @	CONCRETIONS @	SLOPE	DRAINAGE	PARENT ROCK	AGE OF P.R.
1.	Kawa	5YR 4/4	cl	mfr	2-3m-lsbk, 3fcr	5 YR 4/4 **	cl	mfr	2-3m-csbk & fcr	5 YR 4/4	c	wss	2msbk & 3fcr	3"		2-3°	imp.	intrusive dolerite	Early Pliocene
2.	Livodoi	10YR 4/3	l	mfr	3f&msbk	10YR 5/6 **	cl	mfr	1-2fsbk & vf-fgr	10 YR 5/8	cl	mfr	2-3f&vfsbk → mcr	18"	(Fe) 6"	10°	free	porphyritic-micro-basalt	Late Eocene-Oligocene
3.	Bombalai	7.5 YR 3/2	sl	mfr	2msbk, bk & cr	7.5 YR 4/4 **	cl	mfr	2msbk, bk & cr	7.5 YR 4/4	scl	mfr	2msbk-bk	9"		30°	free	dark gray vesicular basalt	Mid. Quarternary
4.	Besar	10 YR 6/3	sil	mfr	2msbk	10 YR 6/4	sicl	ws	2msbk	10 R 5/8 (m) 5YR 6/8, 2.5 Y 6/4	c	mfr	2-3 msbk	15"		30°	imp.	intrusive dolerite	Early Pliocene
5.	Tiger	10R 3/4	sl	mfr	3mbk	10 R 4/4 **	cl	mfr-fi	2-3mbk	10R 4/6	sl			18"		35°	free	purple vesicular basalt	Up. Quarternary
6.	Baba	10YR 3/2	cl	mfr	2-3 fsbk	10 YR 5/6	cl	mfr-fi	2vfsbk	10 YR 5/6 (m)	c	mvfi	2vfsbk	16"	(Mn) 8½" (Fe) 1½"	10°	free	porphyritic-micro basalt colluvium	Late Eocene-Oligocene
7.	Kobovan	10YR 4/3	l	mfr	2mfsbk, 1fgr	10 YR 4/4	cl	mvfr-fr	2-1msbk → fgr	10 YR 4/4	cl|c	mvfr-fr	1f-msbk	10"		17°	free	porphyritic-micro basalt colluvium	Late Eocene Oligocene
8.	Sinaputan	10 YR 4/4	cl	mfr	3m-c sbk	7.5 YR 4/4	c	mfr	2m-fsbk & fgr	5 YR 5/6	c	mfr	2msbk + 3fcr	15"		15°	v. free	porphyritic-micro-basalt	Late Eocene-Oligocene
9.	Nerelud	10YR 4/4	cl	mfi	2mfsbk & 1fgr	10YR 5/6	cl	mvfr-fr	2mfsbk & 1fcr	10 YR 5/8 (m)	cl|c	mfr	2fsbk & 1fgr	31"		12°	free	micro-basalt colluvium	Late Eocene-Oligocene
10.	Mengkadait	5 Y 5/4	cl	mfr	2fsbk & fgr	2.5 Y 6/2	cl	mfr	1fsbk & fgr	10 YR 5/8	cl	mfr	1fgr	14"	(Fe+Mn) 5"	0°	imp.	porphyritic-micro-basalt	Late Eocene-Oligocene
11.	Quoin	7.5 YR 4/3	c	mfr	2-3 fmbk & 3fcr	5 YR 4/3	c	mfr-fi	2msbk-bk 3fcr					17'+		2°	v. free	red basalt	Up. Quarternary
12.	Mostyn	7.5 YR 3/2	c	mfr	3mgr	5 YR 3/4	c	mfr	3msbk-bk & fcr	7.5 YR - 5 YR 3/3	c	mfr	3mbk & fcr	32"	(Mn) 3"	0°	v. free	gray vesicular basalt	Mid. Quarternary
13.	Table	7.5 YR 3/2	cl	mvfr	2msbk & 3fcr	7.5 YR 4/3	c	mvfr	1-2mbk & 3fcr	7.5 YR 4/4 ***	c	mfr	1-2mbk & 3fcr	17'+		5°	v. free	dark gray vesicular basalt	Mid. Quarternary
14.	Antayan	10 YR 5/2	l|cl	dh-vh	sbk-cr	10YR 5/6 (m)	c	mfi-vfi	sbk-bk	10YR 7/6 (m)	c	wss&p	massive	33"		5°	imp.-free	basalt colluvium	Up Pliocene
15.	Bilai	7.5 YR 5/6	cl	mfr	2msbk → fgr & cr	5 YR 5/8	cl	mfr	2msbk → 3fcr	5YR 5/8	cl	mfr	2msbk -3fcr	5'+	(Fe) 3"	4°	v free	porphyritic-micro-basalt	Late Eocene-Oligocene
16.	Tarat	7.5 YR 5/8	cl	mfr	cr	7.5 YR 5/8	c	mfr	cr	7.5 YR 5/8	c	mfr	cr	3.5'	(Fe) 10'	30°	free	sheared (serpentinised) basalt	Up. Pliocene
17.	Kuantan	10 YR 3/4	cl	mvfr	3mcr-sbk	5YR-7.5YR 4/4	c	mvfi	1-2fcr					7.5'	(Fe) 3.5'	14°	v. free	vesicular olivine basalt	Eocene
18.	Pelawan	10 YR 3/3	c	mvfr	1fcr	10 YR 4/2	c	mfi	3msbk	10 YR 4/3	c	mvfi	3mcsbk	5'	(Fe?) 3'	1°	imp. below 3'	vesicular olivine basalt	Eocene
19.	Jerangan	10 YR 5/4	c	mfr	2m-csbk & 3fcr	10YR 5/6	c	mfr	2-3msbk-bk 3fcr	7.5 YR 5/6 ***	c	mfr	2-3mbk & 3fcr	17'+		10°	v. free	dark gray vesicular basalt	Lwr. Quarternary
	Tungud°	10 YR 4/2	sicl	mfr	3fsbk					10 YR 4/4	cl	mfr	2-3vf-fsbk & fgr	1½"		35°	v. free	porphyritic-micro-basalt	Late Eocene-Oligocene
	Kinarut°	7.5 YR 4/2	l	mfr-fi	2-3msbk & 1fgr	10YR 4/3 - 7.5YR 4/2	l|cl	mfr	2-1fsbk & fcr	7.5 YR 4/4	cl	mfr	1fsbk & fgr	9"		23°	free	porphyritic-micro-basalt	Late Eocene-Oligocene
	Sedong°	10 YR 4/4	c	mfr	cr					10YR 5/4 - 7.5YR 5/6	c	mvfi	cbk	6"		23°	v. free	basalt (may be serpetinised)	Up. Pliocene

* Assuming all colours have been recorded moist. ** These horizons are more AC than B. *** These horizons are more B or BC than C. ° Not in weathering sequence due to a lack of chemical data. (m) Mottled horizon

attempt that has been made to equate them. In addition to these two areas, basic rocks have been located in the ulu Segama area, but as yet no information is available on the nature of the soils in this area. (see Fig. 1.)

a) Semporna Peninsula Region

Vulcanism in the Semporna Peninsula has been divided into two main phases - the Older Volcanic Rocks of Pliocene age and the Younger Volcanic Rocks of Quarternary age (Kirk 1962). A variety of rock types are found amongst the Older Volcanic Rocks and although some basic lavas do occur, the only soils on rocks of this period are the Kawa and Besar sub-families which are found over intrusive dolerites +. Dolerite, strictly speaking, is not an effusive rock, but it is included here because of its close association with basalts as the parent rock of soils in other regions.

The Younger Volcanic Rocks include a variety of basaltic lavas which vary from a light to dark gray or black in colour, and from dense and non-vesicular to frothy and pumiceous and texture (Kirk 1962 pp. 88). The soils formed vary from the Bombalai, Mostyn and Table sub-families on dark gray non-vesicular and vesicular lavas, through the Jarangan sub-family to the Tiger and Quoin sub-families on red scoriaceous lava Table 2).

The basic rock derived soils from the Semporna Region have been classified by Paton (pp.28 - 29) as follows -

Table 3

Geomorphic Unit	Age of Parent Rock	Sub-family	Family
Soils developed on hills and mountains	Early Pliocene	Besar	BESAR
	Quarternary	Bombalai Tiger	BOMBALAI
Soils developed on high level plateaux	Quarternary	Jarangan Table Mostyn Quoin	TABLE
Soils developed on the erosional coastal platform	Early Pliocene	Kawa	KAWA

Paton (pp. 56 - 60) indicates, that despite differences in the age of the parent rocks, and the almost continuous exposure of the older rocks since their formation to the processes of weathering, the Besar and Kawa sub-families have weakly developed profiles by comparison with the Table Family soils. In the case of the Kawa sub-family this is 'because of the difficulty of development of a deeper weathered profile in such a situation and on such resistant rocks'; and for the Besar sub-family, the weak profile development

+ The Membalua sub-family is supposedly derived from intermediate and basic ashes, lavas and agglomerates of this age. This type profile however, (Paton pp.41) is developed from andesitic ash overlain by creep material of questionable origin and consequently is not included in this discussion. Similarly, in the case of the Tinagat sub-family which is derived from intermediate to basic agglomerates, the data presented is insufficient to warrant its inclusion as a basic effusive rock derived soil.

is directly related to the steepness of the terrain. Very little is said about the Table and Bombalai Families, but it is inferred that the climate and strongly oxidising environment are responsible for the development of these soils.

b) Labuk Valley Region

The primary subdivision in the classification of the basic rock derived soils from this region is on the basis of terrain. There is a furt subdivision into colluvial or residual sites with drainage or concretionary development playing a tertiary role. (see Table 4).

Two soils, the Tungud and Kinarut series, developed over mountain (35°+) and steep (30 - 35°) terrain, have been described in the section on basic rock derived soils in the report on the Labuk Valley, but due to a lack of chemical data, they have not been discussed in this paper.

Table 4

Terrain	Nature of Site	Drainage/Concretions	Series
Flat - undulating 0 - 5°	residual (laterized)	free	Bilai
		imperfect	Mengkadai
Rolling to Easy Rolling 5 - 15°	residual	concretionary	Livodoi
		non-concretionary	Sinaputan
	colluvial	imperfect	Baba
		free	Kobovan
Mod. steep 15 - 30°	residual	free	Nerelud

The general sequence of weathering is from the skeliform Tungud series (see Table 2), to the freely draining, concretionary Bilai series on flat to gently undulating terrain. This sequence is modified to some extent by site and soil stability factors.

The basic rocks of the Labuk Valley region have been described by Fitch (1958) as ranging from glass to micro-crystalline and fine grained basalt (commonly as micro-porphyritic and more rarely amygdaloidal basalts) and intrusive dolerites.

2. Sarawak

In the available publications from Sarawak, (Andriesse 1964 and 1965) three soils are defined as occurring on basic effusive rocks. They are the Tarat series and Antayan series, which are grouped as follows -

Tarat Family - soils with a reddish brown to strong brown colour. Crumbly and friable throughout the profile;

Antayan Family - soils with a strong yellow to olive yellow colour and weak blocky structure;

(apparently each Family is represented by only one series) - in the Great World Soil Group of 'Lateritic Soils'

The third soil is the Sedong series which belongs to the Sedong Family of Skeletal soils. Due to a lack of chemical data, this soil has not been discussed in detail in this paper (see Table 2).

Andriesse (1964 - Table 4) notes that the Antayan series is developed from basic igneous rocks, but then, in 1955 (pp.36) he considers that this soil is derived from 'more andesitic rock types'. In a later note (pers. comm.) he indicates that the modal Antayan is on basic igneous rocks (probably basalt) but with the reservation that the Antayan as it exists at present may be incorporated into the Tarat Family, but restricted to those soils from basic igneous rocks which contain fragments of volcanic glass.

For the purpose of this paper, the original modal definition is retained (summarised in Table 1 and 2) with the following notations - 'The Tarat Family may represent an older stage in soil formation than the Antayan family' (Andriesse 1965 pp. 36 and (1964 pp.25) - 'It is suggested that the yellow blocky Antayan series have developed under more wet conditions than existing in the Tarat series'.

Present information indicates that these soils have been described from the First Division only. Figure 2 shows distribution of basic extrusive rocks in the First, Second and Third Divisions. The upper Pliocene age assigned to these rocks in this paper, was obtained by extrapolation of data from a report by Kirk (1957) on the geology of part of the Third Division, and consequently, any conclusions regarding these soils in this paper are only tentative until the age of the parent rock is confirmed.

3. Malaya

In the Malayan peninsula, soils derived from basic effusive rocks have been located in only one area; in the region of Bt. Goh near Kuantan, Pahang, and adjacent areas of southern Trengganu. (see Fig. 3.) The rocks are a 'compact micro-crystalline, vesicular, olivine basalt' with associated minor occurrences of non-amygdaloidal 'titanaugite dolerite and olivine dolerite' as dykes.

Only two series have been recognized, the Kuantan clay and the Pelawan clay. Due to the rather limited occurrence of the latter soil the two are almost invariably considered as one unit, the Kuantan Family. The Kuantan clay is a deep yellowish brown to reddish yellow soil with the stronger colours occurring on the steeper slopes which may range from almost level to 15°; rarely to 20°. By contrast, the Pelawan clay is a much shallower soil, giving way at about 4 or 5 feet to a compact, wet, gravelly layer, often with a peculiar greenish gray colour, and found on level or very gently undulating sites with impeded drainage. (Panton 1958 (1) and (2). These soils have been recently classified by Leamy (pers. comm.) as Dark Red Ferralsols.

It is interesting to note that Fitch (1952) considered that "Alteration of dolerite by weathering penetrates more deeply than in basalt".

Determination of the Degree and Sequences of Weathering

Before any conclusions could be drawn, it was found necessary to ascertain accurately the relative degree of weathering of each soil.

1. Method

It was decided that the best method of determining the degree of weathering of the various basic rock derived soils of Malaysia, was to compare them chemically. To simplify these comparisons arbitrary depths were choses at 6", 12", 24" and 36". (Such depths incorporating A and B horizons of all soils and the C horizons of the shallower soils). Single phase graphs - depth plotted against each set of chemical data - were drawn to aid in interpretation. Of all of the data available four sets emerged as being the most useful for indicating the trend of weathering. These were the $(Ca^{++} + Mg^{++})/K^{+}$ ratio; the exchangeable K^{+} meq/100gm, Base Saturation, and the Cation Exchange Capacity; which are discussed below.

Each of these four groups was then subdivided, (see below for further data on these sub-groups) and each sub-group was assigned as arbitary value, ranging from 5 to 1 in order of weathering. The soils falling within each sub-group acquired the value of that sub-group. These values were then totalled up for each soil giving a sequence of very weak weathering to very strong weathering ranging in value from a theoretical 20 to 4. From this roughstatistical analysis the groupings of soils as arranged on Tables 1 and 2 emerged.

2. <u>Discussion on the Chemical Data Used to Determine the Weathering Sequence.</u>

a) <u>Calcium + Magnesium/Potassium Ratio</u>. $(Ca^{+}Mg)/K$

Initially it was felt that the calcium/magnesium ratio would give a good indication of the degree of weathering in these soils; but in general, the figures from this ratio did not give an easily interpretable pattern.

Instead, the (Ca+Mg)/K ratio was employed and this gave quite a good picture of the course of weathering. Paton (1961 pp.51) notes that potassium, though present in small amounts when compared with the divalent cations, is relatively concentrated in the more leached soils and concludes "It would seem that most of the potassium is removed in the very early stage of weathering, while a small amount is very much more resistant to removal than the divalent cations", with respect to the soils of the Semporna Peninsula.

Thus, as weathering proceeds, the (Ca+Mg)/K ratio would increase from about 10 (average figure as calculated from analyses of a number of basic effusive rocks - see Table 5), to about 100 for very weakly weathered soils and descending gradually to about 1, for the very strongly weathered soils. This would correspond with the initial removal of K^{+} followed at a more leisurely rate by the more even removal of Ca^{++}, followed by Mg^{++}. At some later stage of weathering a second phase of K^{+} would be evenly and gradually removed.

In order to determine the weathering sequence in the Malaysian soils derived from effusive basic rocks the following sub-groupings* for the (Ca+Mg)/K ratios were used:-

1. (Ca + Mg)/K ratio greater than 60.
2. (Ca + Mg)/K ratio ranging between 60 - 10.
   a) even decrease with depth.
   b) initial increase followed by decrease with depth.
3. (Ca + Mg)/K ratio less than 10.
   a) even decrease with depth
   b) initial increase followed by decrease with depth.

Table 5 indicates the relative size of the (Ca+Mg)/K ratios for four types of basic rocks found in the Kuantan District Malaya, and the ratios of total (Ca+Mg)/K and exchangeable (Ca+Mg)/K from the two soils derived from a mixture of these rocks. For comparison the (Ca+Mg)/K ratios are given for a basalt from Indonesia (Mohr & van Baren pp.155) and the lateritic earth weathering product from that basalt.

TABLE SHOWING (Ca+Mg)/K RATIO IN VARIOUS BASIC ROCKS AND THEIR WEATHERING PRODUCTS.

Table 5

	Total (Ca+Mg)/K	Exchangeable (Ca+Mg)/K	
1. Olivine basalt	7.50		from Fitch (1952) pp.41
2. Nepheline basalt	10.80		
3. Med. grained dolerite	9.96		
4. Porphyritic dolerite	10.20		
5. Kuantan Series	11.44	3.15	
6. Pelawan Series	6.23	4.25	
7. basalt (Indonesian)	9.98		from Mohr & Van Baren pp.155.
8. lateritic earth	2.19		

b) Exchangeable Potassium

Exchangeable potassium figures did not prove a very satisfactory indicator of the degree of weathering. In general there should be a distinct drop in K^+ content, at least enabling a separation of the very weakly and weakly weathered soils from the moderately and strongly weathered soils.

A sub-grouping as follows gave a reasonably accurate picture of weathering.

1. K^+ content generally greater than .15 meq/100 gm.
   a) increase in content with depth
   b) decrease in content with depth
2. K^+ content ranging between .15 and .05 meq/100gm.
   a) less than .10 above 12" - greater below
   b) less than .10 below 12" - greater above
3. K^+ content less than .10 meq/100 gm.
   a) generally less than .05 meq/100 gm.
   b) generally between .05 and .10 meq/100gm.

Variations in K^+ content, especially in the less strongly weathered soils, probably reflect the mineralogical nature of the parent rock.

c) Base Saturation

Base saturation indicates the extent of leaching (Metson 1961). Consequently low base saturation indicates strong leaching and vice versa. Normally, in an environment of rapid weathering and a high rainfall, intense leaching is associated with strong weathering. The soils were arranged according to BS % into the following groups, showing an increasing extent of leaching, and, by inference, an increasing degree of weathering:

* All sub-groupings are arranged in order from very weakly weathered to strongly weathered.

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1. Base saturation greater than 50%
2. Base Saturation ranging between 15 -50%
   a) wide range - increasing with depth
   b) narrow range - decreasing with depth
3. Base saturation ranging between 6 -15%
4. Base saturation less than 6%

d) Cation Exchange Capacity

The clay content of a soil normally considered to be a reasonable indicator of the degree of weathering. However, in the absence of adequate data from mechanical analyses, the Cation Exchange Capacities have been used instead. Metson (pp. 171) notes that the C.E.C. is a property, mainly of the clay, and consequently variations in C.E.C. should indicate differing clay content, and so differing levels of weathering.

The following sub-groupings have been employed:-

1.	High Values	mod. wide range	24 - 38 meq/100gm
2.	Medium to High Values	wide range	10 - 30 meq/100gm.
3.	Medium to Low Values	moderate range	7 - 14.8 "
4.	Low Values	narrow range	6 - 9 "

The relationship with weathering is not quite as satisfactory as it might be as two thirds of the strongly weathered soils fall into group 3 rather than group 4. However, comparison of the C.E.C. with clay content of some of the soils as shown on Table 1 reveal that there is apparently no simple relationship between weathering, clay content and C.E.C.

3. Results

a) Degree to Which the Soils Have Been Weathered

From the statistical analysis it was possible to arrange the soils into six major groups -

1. Very Weakly Weathered - Kawa, Livodoi, Bombalai.
2. Weakly Weathered - Besar, Baba, Tiger, Kobovan.
3. Weakly - Moderately Weathered - Sinaputan.
4. Moderately Weathered - Nerelud, Mengkadait.
5. Moderately - Strongly Weathered - Quoin, Mostyn, Table.
6. Strongly Weathered - Antayan, Bilai, Tarat, Kuantan, Pelawan, Jarangan.

The last group being separable into 3 minor groups indicating slightly different grades within the strongly weathered group.

This order for these soils has been used in recording them in Tables 1 & 2. Table 1 indicates the four factors used for differentiating between these soils on a weathering basis and includes, pH and clay% age figures as additional information. Table 2 reveals basic morphological and site information about each soil.

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b) Comparison of Physical and Chemical Aspect of Weathering

With regard to soil colour, two broad groups, especially when observations are restricted to the B horizons (Table 4), emerge:-

1. yellow - yellowish brown - brown group, and
2. yellowish red - reddish brown - red group.

In contrast to the opinion expressed by Paton (pp. 61) where the weathering sequence of the Table family is given as red (Quoin) ⟶ brown (Table ⟶ yellowish brown (Jarangan) with increase in age the writer feels that the colours of the soils discussed herein are an expression of the nature and form of the parent material, and as such, do not directly imply a weathering sequence. Rather the two broad groups:

1. yellow - brown and
2. yellowish red - red represent two independent weathering sequences.

These sequences can be sub-divided on the basis of water movement within the profile. This division is based on the accumulation of ferric and manganiferous concretions in the A or upper part of the B horizon of some of these soils. Such an accumulation, according to Mohr and Van Baren (pp. 321), takes place under conditions of ascending and descending water movement within the profile; in contrast to the regions where the movement of soil waters is continually downward.

The soils derived from basic effusives in Malaysia may therefore, be divided into 4 main weathering sequences, based on the colour of the solum and water level fluctuations within the profile. (See Table 6).

The general trends in the four chemical factors; (Ca+Mg)/K; K^+ meq/100g; B.S.% and C.E.C.; have been discussed above, and the conclusions from the four factors have resulted in the weathering sequences from the Kawa to the Jarangan soils as already mentioned. However some interesting points do emerge when examining the chemical data connected with the weathering sequences as outlined in Table 6.

Table 6

WEATHERING SEQUENCES IN SOILS DERIVED FROM BASIC EFFUSIVE ROCKS

	1. Yellow-Brown	(B. Horizon)	2. Yellowish red-Red (B.Hor	
	Continuous downward water movement A	Alternating up & down water movement B	Continuous downward water movement A	Alternati up & dow water mov ment B
Very Weakly Weathered	Bombalai	Livodoi	Kawa	
Weakly Weathered	Besar Kobovan	Baba	Tiger	
Weakly - Mod-Weathered	Sinaputan			
Moderately Weathered	Nerelud	Mengkadait		
Moderately - Strongly Weathered	Table		Quoin	Mostyn
Strongly Weathered	Antayan Tarat Jarangan	Pelawan	Kuantan	Bilai

(i) In the yellow - brown sequence of soils with continuous down movement of water (1.A) the exchangeable potassium content is always lower tha that for the corresponding soils at that level of the weathering in the other three groups.

(ii) The yellowish red to red sequence of soils with alternating up and down water movement throughout the profile (2.B) shows a slightly higher base saturation when compared with other soils of the same group; and the (Ca+M /K ratio is unusually high in the strongly weathered component.

Nature and Age of the Parent Rock

The nature and age of the parent rocks underlying the various soil has been mentioned earlier. Table 8 attempts to summarise this information and present it in a chronological sequence.

If all of these basic rocks were of a homogeneous texture the pr would be simple, however they range from hard fine-grained micro-basalts and intrusive dolerites to scoriaceous lavas of the 'aa' type. Since rocks contain pores or vesicles present a far greater surface area to the processes of weathe than the hard massive rocks the former will obviously weather far more rapidly than the latter. Similarly, as pointed out by Fitch (1952 pp.40), the coarser th texture of these rocks the more rapidly they weather.

Table 7 groups the various parent rocks into grades of weathering

Nature of the Terrain

As always, terrain plays a significant role in determining the rate ...athering of the soils derived from basic effusives throughout Malaysia. ...er, perusal of the slopes recorded in Table 2 & 8, quickly reveals that ...is no simple relationship between degree of weathering and soil slope.

Plotting soil slope against soil depth does produce a rough pattern ...Fig.4) which illustrates the following points.

1. Very weakly weathered soils have little relation to slopes;
2. Weakly and moderately weathered soils appear to have a strong relationship to the nature of the slope.
3. Moderately-strongly and strongly weathered soils (principally these with more than 30" of solum over the C horizon) have a weak relationship with terrain.
4. Those soils characterised by alterating upward and downward movement of water within the profiles (1.B and 2.B of Table 6) all occur on slopes of less than 10° (generally less than 4°) and have 60" or less of solum over the C horizon. These six soils show a good 'very weakly weathered-strongly sloping-shallow' to strongly weathered-level-deep' trend.

Conclusions

It appears, that, despite differences in the nature and age of the ...t rocks, the soils derived from basic effusivesin Malaysia can be ...ed into two weathering sequences. Contrary to previous opinion these ...quences do not show a colour transition from red to yellowish brown ...eathering, but rather retain a relatively uniform soil colour through- ...riations in colour, texture and depth of soil within each of these ...ces are accomodated by sub-dividing each sequence into a part A and ...B dependent upon the direction of water movement within the profile.

These sequence may be expressed as follows in terms of degree and ...of weathering.

Increase in degree and depth of weathering ⟶

Bombalai ⟶ Besar ⟶ / Kobovan ⟶ Sinaputan ⟶ Nerelud ⟶ Table ⟶

⟶ Table ⟶ Antayan ⟶ Tarat ⟶ Jarangan

Livodoi ⟶ Baba ⟶ Mengkadait ⟶ Pelawan

Kawa ⟶ Tiger ⟶ ? ⟶ Quoin ⟶ Kuantan

? ⟶ Mostyn ⟶ Bilat.

In the future more attention should be directed towards the (Ca+Mg) ...io as an indicator of weathering in soils derived from basic rocks.

Perhaps the greatest single factor contributing to the weathering ...ls from basic effusive rocks is the nature of the particular rock ... The coarser grained and more vesicular the rock, the more rapidly ...thers.

Table 7

TABLE SHOWING THE SUSCEPTIBILITY OF BASIC EFFUSIVE ROCKS TO WEATHERING

Weatherability	Parent Rock	Geologic Age	Loca
Highly susceptible	dark gray vesicular basalt purple vesicular basalts dark gray vesicular basalts	Lower Quarternary Up. Quarternary Mid. Quarternary	Semp
Moderately Susceptible	sheared basalts intrusive dolerites vesicular nepheline & olivine basalts porphyritic basalts	Up. Pliocene Lwr. Pliocene Mid.-lwr. Eocene Eocene-Oligocene	Sar Sem Mal Lab
Weakly Susceptible	fine porphyritic & micro-basalts	Eocene-Oligocene	Lab

...

Table 8

NATURE AND GEOLOGIC AGE OF BASIC EFFUSIVE ROCKS IN MALAYSIA

ERIOD		PARENT ROCK	SOIL	SLOPE	NO	LOCATIO
UARTERNARY	Upper	purple vesicular basalt	Tiger	35°	5	SABAH
			Quoin	2°	11	
	Middle	dark gray vesicular basalt	Bombalai	30°	3	
			Mostyn	0°	12	
			Table	5°	13	(Sempor
	Lower	dark gray vesicular basalt	Jarangan	10°	19	
LIOCENE	Upper	sheared (serpentinised) basalt	Antayan	5°	14	SARAWAK
			Tarat	30°	16	
	Middle					
	Lower	intrusive dolerites	Kawa	2-3°	1	SABAH
			Besar	30°	4	(Semporn
OCENE	Upper					
	Middle					
	Lower					
OCENE	Upper					
	Middle					
	Lower	fine porphyritic and micro basalts with associated intrusive dolerites	Livodio	10°	2	SABAH (Labuk)
NE	Upper		Baba	10°	6	
			Kobovan	17°	7	
			Sinaputan	15°	8	
			Nerelud	12°	9	
			Mengkadait	0°	10	
			Bilai	4°	15	
	Middle	vesicular olivine and nepheline basalts and some intrusive dolerites	Kuantan	14°	17	MALAYA
	Lower		Pelawan	1°	18	

The terrain rate of weathering relationship appears to be a rather complicated one and may best be summarised as saying that after 30" of rock free solum is developed, soil slope has little effect on the rate of weathering, until the terrain is such that drainage is restricted to some degree causing fluctuations in water level within the profile. At this stage the depth to which weathering proceeds appears to be restricted, although weathering still progresses in the upper horizons.

Acknowledgements

Thanks are due to J.P. Andriesse who made available a wealth of information on the Tarat and Antayan series from Sarawak. Inche M.L. Leamy gave invaluable advice and encouragement.

Figures 1 and 2 were drawn from maps compiled by Fitch (1961) and Figure 3 was drawn from a base map prepared by the Department of Mines, with additional information from Fitch (1952)

References

1. Andriesse J.P. (1964): "Soils and Land Potential in the Serian Development Area". Soils Div'n, Dept. of Agric. Sarawak. Report No: 44/1 pp.97.
2. Andriesse J.P. (1965): "Soil and Land Potential of the Sarawak-Kiri, Samaratan, and Sadong River Basins" Soils Div'n Dept. of Agric. Sarawak. Report No: 59 pp.115.
3. Fitch F.H. (1952): "The Geology and Mineral Resources of the Neighbourhood of Kuantan, Pahang" Geol. Surv. Malay, Mem No: 6 (n.s.) pp. 144.
4. Fitch F.H. (1958): "Geology and Mineral Resources of the Sandakan Area North Borneo" Brit. Borneo Geol. Surv. Mem No: 9.
5. Fitch F.H. (1961) "Sarawak Geological Office Map No: 317".
6. Guha M.M. (1964): "The Effect of Soil Type and Nutrient content on the Fertilizer Requirement of Hevea brasiliensis". (Unpublished paper presented at 1st Malaysian Soil Conference.)
7. Hooper A.D.L. & Ives D.W. (1964): "Report on the Soils of the Labuk Valley Project Area, North Borneo". (Unpublished report to United Nations Special Fund).
8. Kirk H.J.C. (1957): "Geology & Mineral Resources of the Upper Rajang & Adjacent Areas, Sarawak" Brit. Borneo Geol. Surv. Mem. No: 8.
9. Kirk H.J.C. (1962): "Geology and Mineral Resources of the Semporna Peninsula North Borneo" Brit. Borneo Geol. Surv. Mem No: 14.
10. Metson A.J. (1961): "Methods of Chemical Analysis for Soil Survey Samples" N.Z.D.S. I.R. Soil Bureau Bull No: 12 pp. 208.

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SABAH
Scale 1:2,000,000
Miles 10 0 50 Miles
KUDAT
Sugut R.
Labuk Bay
JESSELTON
SANDAKAN
Labuk R.
LABUK REGION
Kinabatangan R.
Segama R.
Pudas R.
Kuamut R.
Darvel Bay
Talankai R.
SEMPORNA PENINSULA REGION
Serudong R.
TAWAU
DISTRIBUTION OF BASIC EXTRUSIVE ROCKS.

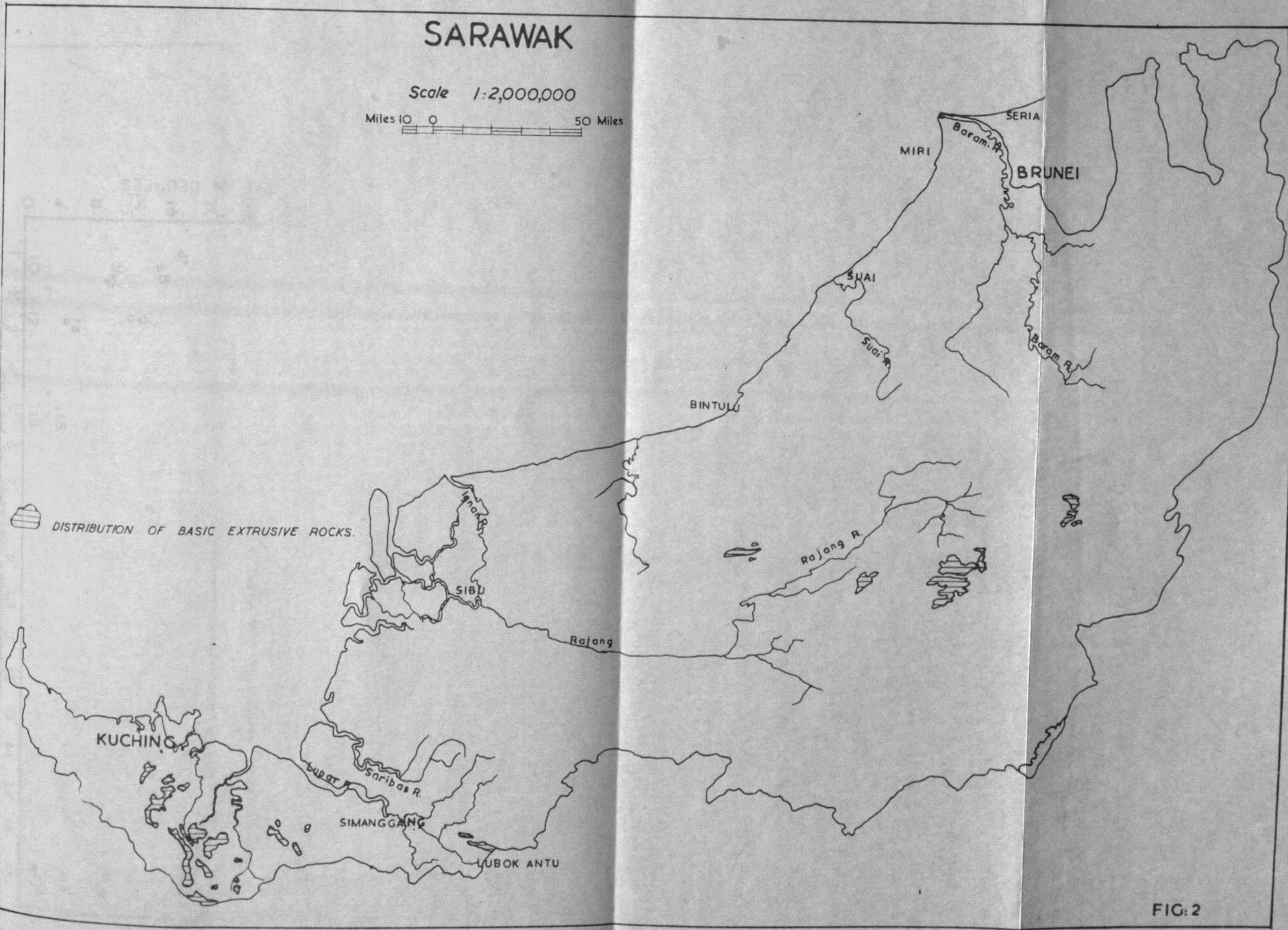
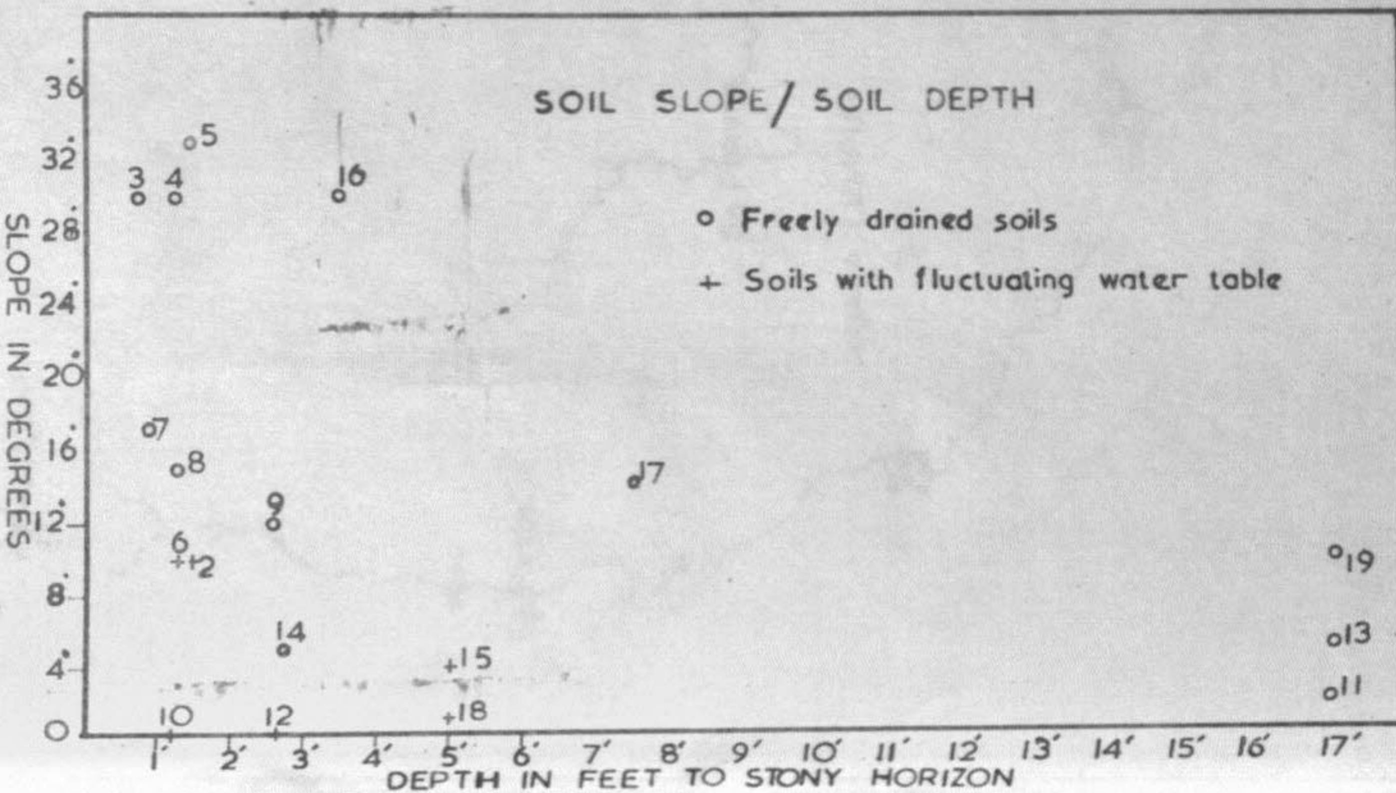

SARAWAK
Scale 1:2,000,000
Miles 10 0 50 Miles
SERIA
MIRI
Baram R
BRUNEI
SUAI
Suai R
Baram R.
BINTULU
DISTRIBUTION OF BASIC EXTRUSIVE ROCKS.
Rajang R.
SIBU
Rajang
KUCHING
Lupar R.
Saribas R.
SIMANGGANG
LUBOK ANTU

FIG: 2

FIG. 4



SOIL SLOPE / SOIL DEPTH
o Freely drained soils
+ Soils with fluctuating water table
SLOPE IN DEGREES
0
4
8
12
16
20
24
28
32
36
1'
2'
3'
4'
5'
6'
7'
8'
9'
10'
11'
12'
13'
14'
15'
16'
17'
DEPTH IN FEET TO STONY HORIZON
3
4
5
16
7
8
9
6
2
14
15
18
10
12
17
19
13
11

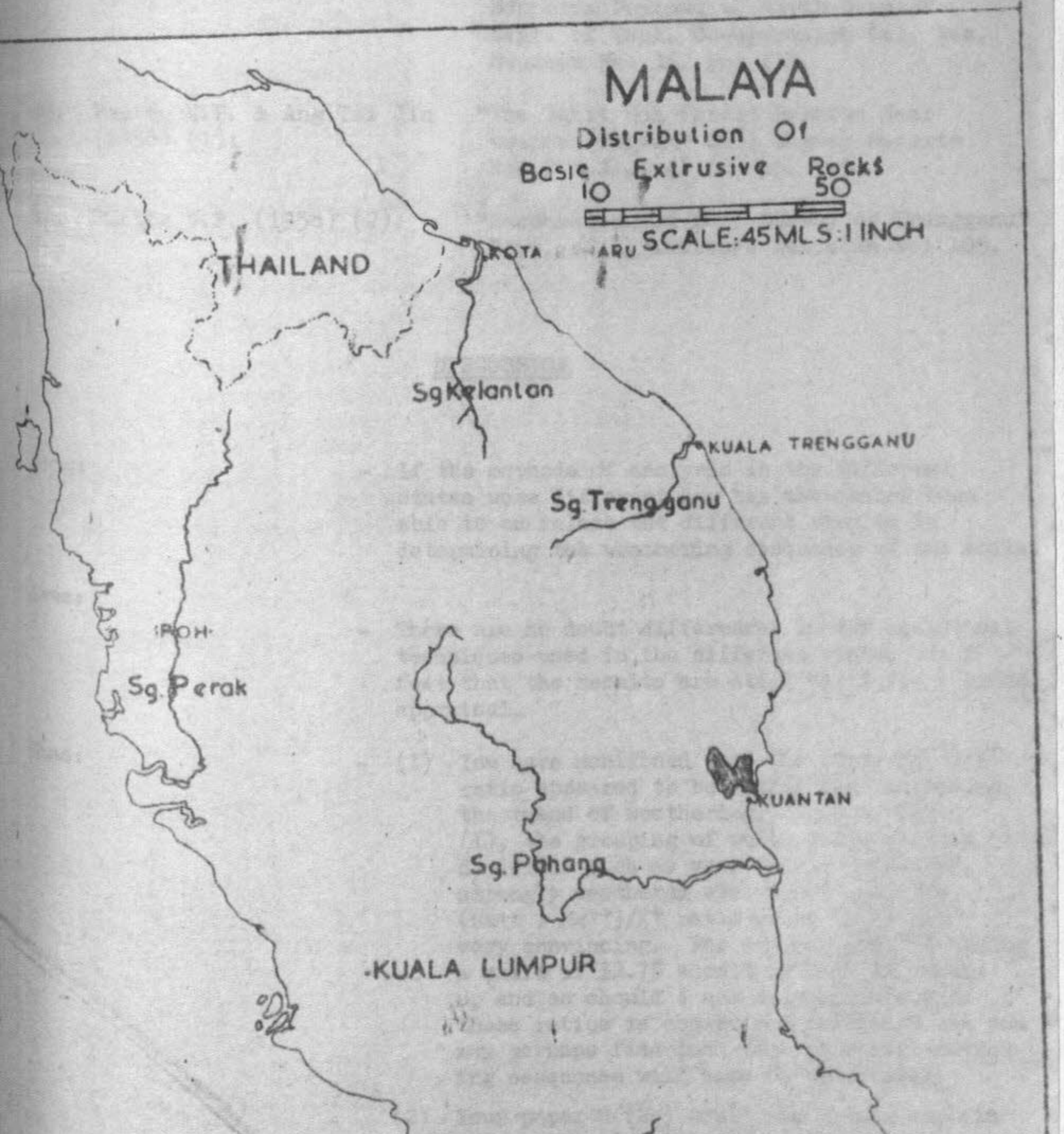

MALAYA
Distribution Of
Basic Extrusive Rocks
10
50
SCALE:45 MLS:1 INCH
THAILAND
KOTA
Sg Kelantan
KUALA TRENGGANU
Sg. Trengganu
IPOH
Sg. Perak
KUANTAN
Sg. Pahang
KUALA LUMPUR
Sg. Muar

FIG:3

11. Mohr E.C.J. & Van Baren F.A.(1959): "Tropical Soils" - N.V. Uitgeverij W. Van Hoeve - The Hague and Bandung 498 pp.

12. Paton T.R. (1961): "A Reconnaissance Soil Survey of the Semporna Peninsula, North Borneo" Dept. of Tech. Co-operation Col. Res. Studies No: 36. pp. 111.

13. Panton W.P. & Ang Tai Jin (1958) (1): "The Bukit Goh Forest Reserve Near Kuantan Pahang" Soil Survey Reports No: 7 M.A.J. 41 (1) pp. 3-9.

14. Panton W.P. (1958) (2): "Reconnaissance Soil Survey of Trengganu" Dept. of Agriculture Bulletin No: 105.

DISCUSSION

Wong: - If the methods of analysis in the different states were different how has the author been able to correlate the different results in determining the weathering sesquence of the soils.

Ives: - There are no doubt differences in the analytical techniques used in the different states but I feel that the results are still valid for a broad appraisal.

Shao: - (1) You have mentioned that the $(Ca^{++} Mg^{++})/K^{+}$ ratio appeared to be useful for indicating the trend of weathering. In your Table (1), the grouping of soils under various divisions such as very weakly weathered, strongly weathered etc. based upon the $(Ca^{++} + Mg^{++})/K^{+}$ ratio seems to be not very convincing. For example soil 15 having a ratio of 32.75 should in fact be pushed up and so should 4 and 6. Regrouping of these ratios is considered essential and you may perhaps find that the proposed weathering sesquence will have to be altered.

(2) Your paper 8 (2b) could you please explain under what circumstances would there be an initial increase of $(Ca^{++} + Mg^{++})/K^{+}$ ratio followed by decrease with depth?

Ives: - The $(Ca^{++} + Mg^{++})/K^{+}$ ratio was one of four basic criteria used in the assessment of the stage of weathering of these soils and therefore it is possible on using any one criterion alone the order of the soils would not be the same as the overall assessment. On the second point there does not seem to be an obvious explanation for the observation.

Dumanski: - Since you have not taken organic matter into account when using the C.E.C. values this might explain the poor correlation between C.E.C. and degree of weathering.

Bailey: - In view of the vary low exchangeable values and the relatively large variation of error encountered in the analysis of such low quantities, the use of (Ca + Mg)/K ratio can lead to considerable difficulties in interpretation. I think much more study has to be done on the extent of the variation of this ratio in each weathering class. The form of the phosphorus might be more indicative of the stage of weathering.

Guha: - There are various chemical factors which can be used for classification purposes but unless they are tested as the author has attempted to do here it is not possible to decide which is the most appropriate. The C.E.C. and base saturation figures given in this paper are in broad agreement with the weathering sesquence presented.

Session C. - Soil Suitability and Land Capability Classification.

Chairman: M. L. Leamy.

(1) "Land Capability Classification in the States of Malaya, Malaysia" by W.P. Panton.

(2) "The Classification and Evaluation of Land in Sarawak" by J.P. Andriesse.

(3) "Soil Suitability Classification for Dryland Crops in Malaya" by Ignatius Wong.

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LAND CAPABILITY CLASSIFICATION IN THE STATES OF MALAYA, MALAYSIA.

by

W.P. PANTON

Prime Minister's Department
Malaya.

SUMMARY

This paper outlines an approach to land capability classification for land use planning purposes which is being applied in the States of Malaya, Malaysia, where data from specially prepared maps showing mineral potentiality, soil suitability and forest productivity are used in the assembly of capability maps indicating the areas best suited to mining, agricultural development, and productive or protective forest, or other resource use purposes.

The land capability maps which are produced on a scale of one inch to a mile (1:63,360) are accompanied by reports which compare the capability classification data with the present use pattern, and outline the broad development opportunities apparent from the contributed resource maps, and these are designed to be of use to development planners and others concerned with the best use of the land within a sound conservation context.

The programme of land capability classification is a closely co-ordinated programme involving a number of Government agencies, and the intention is to prepare maps with accompanying reports for the whole of Malaya within a three-year period which commenced in 1965.

Background

With an average population density of 70 persons per square mile, Malaysia is fortunate in having a relatively low population in relation to her territorial area and large tracts of unused land are available for future development. There are considerable reserves of unexploited minerals, uncultivated soil, uncut forest, and un-utilized water.

Surveys of these and other resources are in an advanced stage, and particular emphasis is given to strengthening the survey organizations which are concerned with the mapping of the exploitable reserves, and to utilizing the results of these surveys for practical purposes of development planning.

For throughout Malaysia today the pace of development is rapid, and new lands are being opened up and new industries developed in accordance with carefully prepared Five-Year Plans. Diversification of both agriculture and industry is of paramount importance, and feasibility studies into new crops and new industries utilizing local produce are constantly being undertaken.

It is apparent that Malaysia can learn from the experiences of other countries, many of which are more economically advanced than herself, in planning for use of the unused areas before the land in question is irretrievably committed to a particular use purpose which may later be found to be inappropriate. In order to do this it is extremely important that the results of surveys and other investigations are co-ordinated for land planning purposes. This in turn implies a spirit of co-operation not only between the agencies conducting such surveys, but also with those carrying out the physical planning and actual development.

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Such conditions exist in the States of Malaya, where an impetus has been given to this work by the pressing need to settle large numbers of landless persons, particularly from the crowded West Coast States, by opening up large areas of unexploited land, particularly in the East Coast States and in the interior which are the places with the greatest potentials for agricultural, forest, and water use development.

Land Capability Classification

Land Capability Classification has been seized upon as being the appropriate technique for translating the technical data amassed by the survey agencies into meaningful terms for the developers and the community at large. The essence of this classification is its simplicity, the intention being to present the data in such a way that it is understandable to those who are not necessarily well informed about the actual resources. The maps which embody this classification are intended to be used as guides to planning by the development authorities, who should thus be able to prepare their development plans with greater assurance, and to direct their efforts into those areas where the most beneficial results can be expected.

The classification is a very simple one, and it divides the land into the following five broad groups:-

Class I	Land possessing a high potential for mineral development and therefore best suited for mining.
Class II	Land possessing a high potential for agricultural development with a wide range of crops and therefore best suited to agricultural diversification.
Class III	Land possessing a moderate potential for agricultural development with a restricted range of crops and therefore best suited to agricultural development with crops having a wide range of soil tolerance.
Class IV	Land possessing a potential for productive forest development and therefore best suited to commercial timber exploitation.
Class V	Land possessing little or no mineral, agricultural, or productive forest development potential but suitable for development as protective reserves for conservation, water catchment, game, aborigine, recreation, or similar purpose, or possibly suitable in the future for productive forest plantations with introduced species.

How Land Capability Classification became established

The story of how Land Capability Classification has come to occupy its present place in the field of economic planning is an interesting one which goes back several years. In 1954 a World Bank mission visited Malaya, and in a comprehensive report this mission recommended the creation of a Land Use Survey team to direct attention towards diversification crop potentials, particularly in the undeveloped areas, and to co-ordinate the survey aspects over the entire resource-use field with emphasis given to agricultural development opportunities. Later, in 1962, a team of experts provided by the Ford Foundation visited Malaya in order to undertake a study of agricultural diversification of the Malayan economy and to report and make recommendations thereon. The report particularly emphasized the need for more soil surveys but advocated that greater attention should be given to surveys of resources generally. Emphasis was also given to this report to the need for utilizing the indigenous forests to better effect, and to ensuring that the permanent forest estate was sited in those areas where it would least interfere with the pressing need to develop more land for agriculture.

In many respects these recommendations were reflecting local sentiment in the technical departments of Government. A degree of co-operation amongst the various resource survey agencies had existed for many years and in some cases this extended to joint field programmes, and a healthy exchange of field data and experience.

During the period of the Malayan First Five Year Plan (1956-60) data collected by the resource survey teams was applied to development problems by means of a certification system, which was introduced to assist in ensuring that land chosen for large agricultural development schemes was suited to the purpose of the scheme, and particularly to the crop which would be the mainstay of the scheme. The certificates, which were insisted upon by the development agencies, principally the Federal Land Development Authority, included a clearance certificate prepared by the Geological Survey to the effect that the area was free of workable mineral deposits, and a similar clearance from the Forest Department indicating that the area had been properly exploited of commercial tree species prior to felling and clearing. A soil suitability certificate was also insisted upon, and this was supplied by the Department of Agriculture which carried out a soil examination of each site before issuing the certificate. In some cases the soil suitability certificates were withheld for several years until the crop in question had been proved suitable by observation of a test plot under the prevailing soil and other environmental conditions, or until the soil had been ameliorated by drainage or other improvement measures.

Within a few years some sixty major schemes, each covering 4,000 acres, and several hundred smaller schemes, mostly between 50 and 300 acres in extent, have been successfully established in various parts of the Malayan peninsula.

The advent of the Malayan Second Five Year Plan in 1961, saw the introduction of the Red Book, a compendium which includes information on the present land use pattern, and proposals for development during the period of the plan, which was prepared for each of the 70 administrative districts and which proved to be a useful device for stimulating development at all levels of the administration. This very practical approach to development is outside the scope of the present paper, but deserves mention as it is a most striking inovation which has contributed greatly to the success of the immensely successful current Malaysian Rural Development drive. It has brought the lower echelons of local expertise into the planning process, and has considerable popular appeal, while it has also helped to instil a realization of the importance of careful selection and sound planning throughout the country.

Experience in dealing with the problems of development led to a general recognition throughout all sectors of Government concerned with land administration and resource development that the present land use pattern, which had largely resulted from a laissez-faire approach to land alienation and a somewhat arbitrary system of allocating land for reserve purposes in the past, was incompatible with the best economic uses over many areas. For example, agricultural development was being forced on to erosion-prone hillsides in some areas where the demand for agricultural land was particularly great, while in neighbouring districts lowland areas of good topography which contained rich soil might be gazetted as forest reserve and remain un-utilized.

Sensible re-allocations which reflected the capability of the land as deduced from existing survey data, usually supplemented by rapid soil reconnaissances, were made from time to time, but only a small scale, and they were ad hoc in the sense that the land use proposals were not interconnected, and no systematic appreciation was yet being carried out on a national basis. These ad hoc plans have however worked very successfully and have culminated in recent years in a proposal to carry out a detailed natural resources appraisal and prepare a development master plan for a particularly large area, covering 600,000 acres, which has been found from reconnaissance surveys to be well suited for a large development scheme incorporating both agriculture and forest exploitation.

The experience gained from these exercises in development planning for better natural resource utilization has emphasized the importance of co-ordinating the data from resource surveys and using it for classifying the broad land use capabilities, and a logical follow-up was to draw up a generally acceptable Land Capability Classification system using fixed criteria to mark the limit of suitability for the different resources, and to apply this classification over the States of Malaya as a whole.

At the same time attention was focused on those fields in which the survey coverage was inadequate or the survey organization was weak due to shortage of trained staff, or deficiencies in equipment, or, as in the case of present land use survey, non-existent, and efforts have been made to remedy these shortcomings with the aid of Colombo Plan assistance. The co-ordinating aspects of the work programme are entrusted to a technical committe which is a sub-committe of the National Development Planning Committee, and the boundaries between the different classes in the capability classification are drawn from specially prepared suitability maps contributed by the main resource survey group covering minerals, soils, and forests.

The Sub-Committe is guided in its judgement by sound conservation principles, and is anxious to make provision for national parks, recreation, and game reserves amongst others in its reports and to include recommendations for reserves for aesthetic and scientific purposes. All the departments with interests in these fields are represented on the committee and an impressive spirit of give and take exists between the different groups.

Opportunities for the future

The Committee is not unaware that this readiness to accomodate the wishes of the different sectional interests, including the minority interests, is largely due to the fact that the States of Malaya has much land which is presently unallocated, and this gives considerable room for manoeuvre. A preliminary assessment of the land use situation and a comparison with the broad capability pattern has very encouragingly shown that while 22 per cent of the area of the country is presently gazetted as forest reserve, 43 per cent of the forested land area is unsuitable for agriculture, mainly on account of steepness of slope, and free of possible conflict with mining interests, and could therefore be utilized as forest estate with little risk of subsequent loss of estate to other land use interests, while of this total perhaps 33 per cent may prove to be productive forest capable of commercial exploitation.

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This same appraisal has indicated that the figure for the area devoted to agriculture could be more than double the present figure, if development is properly planned.

A programme of preparing Land Capability Classification Maps, on a scale of one inch to a mile (1:63,360) which will assist considerably in the development planning process by indicating the details of the capability pattern is now being undertaken and is expected to be completed by the end of 1968.

The results of the Land Capability Classification Programme are published as special reports, with reduced copies of the relevant maps, on a district basis, and these reports highlight the development opportunities apparent from the survey material available for each district for the information of the district authorities and others, including developers from the private sector.

DISCUSSION

Smallwood: - Does the Economic Planning Unit have the jurisdiction or authority to change the agricultural title of a holding?

Panton: - The Economic Planning Unit is largely an advisory body.

Wyrley-Birch: - Is there provision for national parks in your land capability exercise?

Panton: - Before this can be properly done we need to know how much game potential there is within and without the present game reserves. These reserves are concentrated in Johore and Pahang which also possess the highest agricultural potentials.

Andriesse: - Would the phrase "Recommended Land Use" be more applicable than "Land Capability" since the latter term is internationally used to indicate agricultural capability mainly.

Panton: - After much discussion we found that the phrase "Land Capability" is more applicable to our circumstances although "Recommended Land Use" may be the nearest alternative.

Bailey: - Is it fair, in view of the considerable data that are available on soils particularly from soil surveys to have only two classes in your final assessment?

Panton: - If more than two classes are catered for the soils resource a similar provision would have to be made for the other resource contributors thus leading to great complexity in the final capability map.

Smallwood: - Mr. Bailey may be interested to know that in Canada soil indexing is being used to assess soil potential and in this assessment the work of the soil surveyor is fully utilized. However, in view of the considerable amount of comprehensive soil data which are necessary it takes about 20 years to develop soil indexing into an effective system. The Malayan effort is in the pioneering stage of such a development.

Kanapathy: - How flexible are these classes of soil as a few years of research may show that land considered unsuitable for agriculture may be really very suitable?

Panton: - If such a situation should arise the change would first be in the soil suitability map and this will be reflected in the capability map.

THE CLASSIFICATION AND EVALUATION OF LAND IN SARAWAK.

by

J. P. Andriesse

DEPARTMENT OF AGRICULTURE, SARAWAK.

1. INTRODUCTION

The ultimate aim of the Sarawak Soil Survey Division as in most countries is to assess the agricultural value of the soil and present such assessments in specific and well defined terms. For this purpose a standard evaluation system is necessary. Such systems are generally called Land Classifications.

Land Classifications are invaluable not only because they interpret complex technical information into simple terms of agricultural usefulness which is of immediate value to planning authorities, but also because they reveal more clearly which limitations for agricultural development are the most serious so that research can be directed towards possible remedies.

In Sarawak during the last 20 years a variety of land evaluation systems for different purposes have appeared on the scene. Many of these concern specific types of land classification while others have little or nothing in common with proper evaluation systems and their existence only adds to the confusion.

The purpose of this paper is to review the land classification systems used in Sarawak, to evaluate their usefulness, and to suggest what system would best serve the present requirements of agricultural development. The basic principles on which such a system could be developed are discussed.

2. TYPES OF LAND CLASSIFICATION

The Bureau of Reclamation Manual of the U.S. Dept. of the Interior (1953, part 2, p.3) defines Land Classification as follows:

> 'Land classification is the systematic appraisal of lands and their designation by categories on the basis of similar characteristics.'

There are many kinds of such classifications serving many different purposes. The Land Committee of the U.N. Resources Planning Board recognises the following categories:

I. Land Classification in Terms of Inherent Characteristics.
II. Land Classification in Terms of Present Use.
III. Land Classification in Terms of Use Capabilities.
IV. Land Classification in Terms of Recommended Use.
V. Land Classification in Terms of Programme Effectuation.

(F.A.O. Dev. Paper No.18, 1952, p.8).

Table 1

Class 1: Land which is flat or almost flat. There is no appreciable amplitude of relief. Some of the best agricultural land falls within this Class but it also includes peat swamps. *0 - 5°*

Class 2: Land with up to 150 feet amplitude of relief but not more than 10° slope. *< 150 ft, < 10°*

Class 3: Land with an amplitude of relief greater than 150 feet but slopes not exceeding 20°. *> 150 ft, < 20°*

Class 4: Land with less than 50 feet amplitude of relief but slopes of 10 - 35°. *< 50 ft, 10 - 35°*

Class 5: Land with an amplitude of relief of 50 - 150 feet and slopes of 10 - 20°. *50 - 150 ft, 10 - 20°*

Class 6: Land with an amplitude of relief of 50 - 150 feet and slopes of 20 - 35°. *50 - 150, 20 - 35*

Land in Class 1 - 6 is considered - on the grounds of topography - to be suitable for agriculture.

Class 7: Land with an amplitude of relief in excess of 150 feet and slopes of 20 - 35°. Land in this Class is considered marginal for agriculture. *> 150 ft, 20 - 35*

Class 8: All land, regardless of amplitude of relief, in which slopes are greater than 35°. Such land is considered unsuitable for agriculture. *<35°.*

I. Land Classification in Terms of Inherent Characteristics

An example of the first type is a slope map prepared from contour data. Such maps have been made by the Soil Survey Division of Sarawak as an aid to soil mapping. Geological maps and soil maps belong also to this category. All such maps, by themselves tell nothing about the present use of the land, nor the usefulness of it, nor do they make recommendations of any kind. In an endeavour to partly overcome this shortcoming in Sarawak a system which classifies the terrain into 8 units by using slope and elevation as classifying factors was developed by the Soil Survey Division so that the usefulness of the terrain for agricultural development could be shown Table 1 give the key for this system. It has proved useful for making a quick appraisal of the topographic value of land for agricultural use.

II. Land Classification in Terms of Present Use.

Land Classifications of this category divide the land in a system of classes or units based on existing use. An example of such a classification is the Land Use Map issued by the Lands and Surveys Department in 1956 (Sarawak Series No.10) which shows a division into cultivation systems (permanent and shifting) and a classification of natural forest types. In a well-developed agricultural country such a map, read against the background of a map of the first category would perhaps give most useful information on the value of certain soil types or land types for certain crops. In these countries there is commonly a close relation between land potential and land use. In a less-developed country this may not be so. Shifting cultivation practises in Sarawak are not normally related to the natural conditions although to some extent this may be the case. Slope, for example, may be a limiting factor in shifting cultivation as may be soil with very poor inherent characteristics. These limits however far exceed those set for a permanent cultivation system which is designed not only to produce crops economically but also to conserve land resources. Therefore, although a Land Use map serves some purpose its indicative value for soil fertility is limited in Sarawak since other factors such as accessibility and availability of land to certain groups of the community have been important in the development of the land-use pattern.

Although these maps are useful they nevertheless do not evaluate land and soil for agriculture.

III. Land Classification in Terms of Use Capabilities

Classifications of the third type predict the results that would follow if the land is used for a certain purpose. There are many types of this classification. More often then not such classifications are the result of a syntheses of maps of the two first mentioned categories and classification units are usually based on soil types or soil mapping units.

It is in this type of classification that the results of soil surveys can be fully employed. We distinguish for instance the Soil Quality maps which aims at the grouping of soils from a technical standpoint, that is the technical qualities important for a certain use of the soils or for their improvement (Vink 1963, p.47). These qualities may be varied and range from erosion hazard, suceptibility to flooding, and permeability. Another type is the Crop Response map indicating the response of a crop on a certain soil type to a certain management (Vink, 1963, p.47). The most important classification of this nature however is the Soil Suitability or Soil Capability Classification which is defined by Klingebiel as: 'the grouping of individual kinds of soil - called mapping units - into groups of similar soils depending on the intended use - called capability units' (1950, p.160). In this kind of classification the limitations to general crop growth or cultivation systems are evaluated by using the natural soil units as a basis for classification. It gives no recommendations in terms of specific crops but only general indications of the most appropriate form of agriculture.

In Sarawak many tentative soil suitability or soil capability classifications have been prepared for different areas, as it was realised that, if the soil map is to be of value to the user some form of interpretation is necessary. In many instances a column has therefore been added to the key of the soil map indicating the tentative suitability of each mapping unit for agriculture. An example of such a key is given in Table 2.

Classifications of this type in Sarawak only satisfy the needs of the particular survey. Although they make the soil map more useful, they do not objectively classify soil capability. They lie between soil capability classifications and advisory classifications, and more often than not the map user forgets about the 'tentative' nature of the classification and takes the suitability rating as final.

It is important to note that these types of land classification, even though they may indicate the optimum use still do not constitute a recommendation as to the actual land use It should be borne in mind that these classifications are made primarily with the object in mind to maintain the fertility level and the present conditions of the land and if possible to improve it. Soil improvement and soil conservation, although in the long run being part of the accumulation of capital in the form of natural resources, are commonly not the primary aim of the landuser. For them the purpose of land use is production, possibly on a high and sustained level and they therefore have neither the motive nor in most cases the means for the safeguarding of natural resources unless earnings from the land are sufficient.

One may mention the case, common in Sarawak, of a farmer using shallow soil on very steep slopes for profitable cultivation of pepper because apart from slope soil conditions are favourable. Pepper cultivation requires clean weeding and terracing which is normally not done. Both factors accellerate erosion. Although the farmer may accumulate some wealth within a short time by adopting such a method he is ruining land which could be used almost indefinitely - but with a slower return - for a permanent tree crop.

Table 2

Example of a Soil Map key showing soil types with Tentative Agricultural Suitability, as used in Sarawak

GREAT SOIL GROUP	MAPPING UNIT	ACREAGE	MAIN CHARACTERISTICS	SUITABILITY
Red-Yellow Podsolics (Upland members)	Mrt Merit family drainage phase 1	1870	Moderately well drained, generally shallow (less than 30 inches deep), weakly mottled, fine textured soils.	Suitable for rubber and with good management for pepper.
	Mrt Merit family drainage phase 2	107	Imperfectly drained, generally shallow, strongly mottled, fine textured soils.	Suitable for rubber. Drainage needed in flat terrain.
	Bkn Bekenu family drainage phase 1	310	Moderately well drained, generally shallow heavy loamy soils; weakly mottled.	Suitable for rubber and with good management for pepper.
	Bkn Bekenu family drainage phase 2	23	Imperfectly drained, generally shallow, heavy loam soils; strongly mottled.	Suitable for rubber. Drainage needed in flat terrain.
Grey-White Podsolics and Podsols.	Srt/Bso Saratok/ Buso family association	25	Saratok: gravelly loamy sands to sandy loams, porous, podsolised. Buso: gravelly loamy sands to sandy loams with strong podsol features and poor drainage.	Unsuitable for rubber and in general for agriculture.
Red-Yellow Podsolics (Lowland members)	Sdu Seduau family	44	Moderately well drained to imperfectly drained heavy loams with strong mottling in lower subsoils. Frequently overlying poorly drained shales.	Suitable for rubber and if irrigated for wet padi cultivation.
Recent Alluvium	Trb Terbat family	18	Well drained, dark brown to heavy loams overlying boulders.	Suitable for rubber and fruit trees, off-season crops and vegetables. Certain places need drainage. Flooding during wet season is main limitation.
Low Humic Gley Soils	Bjt Bijat family	82	Poorly drained, fine textured soils with strong hydromorphic features such as gleying. Water table generally within 24 inches from surface.	Unsuitable for rubber if drainage is not feasible. Suitable for wet padi cultivation with proper water control.
a	Steep land with slopes over 30 degrees comprising mainly parts of Merit and Bekenu soils (95 acres out of 2180 acres)			Unsuitable for rubber because of susceptibility to erosion.

Soil capability classifications are not therefore a grouping of soils according to the most profitable use to be made of the land from the farmers point of view, and economics are not considered in the compilation of maps of this nature. Classifications taking these factors into account are discussed next.

IV. Land Classifications in Terms of Recommended Use

Classifications in this category are Economic Land Use Classifications and Advisory Land Use Classifications. For the compilation of such classification maps it is necessary not only to study the capacity of the land to produce income but to study, with equal stress, the economic and environmental factors in relation to the crops to be grown. Such maps are in fact the result of long-term agronomy studies, economic research and accumulated experience.

Most of the information required for the compilation of such maps is not available in Sarawak, this being the reason why no attempt has been made to make such maps. However such an undertaking should not be the work of soil surveyors alone, because complex economic and social factors are involved. It may be noted that such work is partly outside the scope of the soil surveyor as has been nicely put by Vink (1963, p.48) as follows:

'The best use of the soil is not only a question of the soil itself, but of various social, political and economic considerations. Sometimes even religious considerations come to the fore, such as the possibility of keeping pigs in a predominantly Islamic country. The soil surveyor must concern himself with soil suitability, and should be very careful not to put himself in the chair of the administrator'.

V. Classifications in Terms of Programme Effectuation.

Such classifications are more than an evaluation or a recommendation. They are plans showing what will be done with the land and are based on Land Evaluation Maps and recommended Land Use Maps. Planting programmes on estates are in this category. Maps showing land subject to different rates of taxation are in this category as are maps showing planned subdivisions of agricultural land and urban area land.

For certain parts of Sarawak, maps of the latter kind are used by the Land Authorities, but they have not always been based on sound principles of land use.

Apart from the classification systems just described, there is one type of Land Classification in Sarawak, perhaps that with the longest history, which has not yet been mentioned. This is a Land Classification based partly on existing ownership in rights and partly on a planned land policy. In Sarawak such maps show a division in Native Customary Right Land, Native Reserve Land, Forest- and Government Reserves, Mixed Zone land and Interior Land. Mixed Zone Land is land which people other than natives are allowed to own. This classification bears no relation to any kind of land evaluation but is mentioned here since land ownership has, in Sarawak, a considerable effect on land use.

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At present the Mixed Zone Land is almost all covered by permanent cultivation while Native Customary Right Land is, in the main, still used for shifting cultivation. Since the mixed zone areas were never selected on the basis of land suitability for permanent cropping the result in some places has been overfarming of the land and subsequent deterioration. In other places this is not the case. Also soils of basically inferior capacity have in some localities proved to be able to support economic holdings. A study of the reasons for these trends in the mixed zone land could prove to be of tremendous value for further land development in Sarawak for permanent cropping.

3. DISCUSSION

This review of existing types of land classification shows that Sarawak lacks useful Land Classification maps which would show the planners and administrators what to expect from the available land resources. Although a variety of classifications have been made for different areas, none of them are based on a system which defines in clear standardised terms what can be expected of the land when used and which can be employed throughout Sarawak.

Such a classification would be of the greatest practical value. Soil surveyors in Sarawak are frequently called upon to prepare maps showing recommended land use. The sound compilation of such maps is impossible at present because of lack in economic data. However, in a developing country such ad hoc recommendations are sometimes necessary but they are extremely dangerous because the soil surveyors does not know, all the economic factors involved.

For a considerable time to come recommendations or advice of this nature will, however, have to be given even though they will be based on meagre information. It is suggested that a sound system of evaluating basic soil properties or soil capabilities be developed. Recommendations could then be based on sound scientific appraisals of soil and land values and could be employed throughout the country. It is realised that the final selection of crops will still remain a difficult problem but with a proper land capability or soil capability classification it will at least be possible to give the alternatives from which a selection can be made by the planning authorities.

The first serious attempt in this direction was recently made by the Sarawak Land and Survey Department who in following discussions with the Soil Survey Division compiled an approximation to a Land Suitability Classification for Agriculture in Sarawak. The key to this Classification is given in Table 3.

For assisting development planning, Sarawak is at present in need for a quick broad appraisal of all available land resources and this key had to be prepared as an interim measure since no time could be lost by too much deliberation. It can readily be seen that this classification is heavily leaning on land characteristics rather than soil characteristics, and although most soil limitations are mentioned, slope is the main one used for the separation of the various classes. Since this system was meant to cover the whole of Sarawak the other soil limitations could not be employed in full in this system because this would have required a soil survey cover of the whole of Sarawak which is not available at present.

The result is that areas without soil survey cover are classified on slopes only while areas which have a soil survey cover are classified on other factors as well. Apart from that the number of soil limitations and not the seriousness of a single soil limitation was used as a classifying factor so that soils having only one limitation are in this system placed at high level of suitability even if that limitation is sufficiently sever to render the soil completely unsuitable for agriculture.

Although having many shortcomings this system indicates with reasonable accuracy the areas which are definitely unsuitable for agriculture because of topographic features while the areas of Classes I to IV can still contain land which on account of adverse soil properties must be regarded as unsuitable. It enables development planners to concentrate their efforts on land-classes 1 to 4, and it will be the task of the Soil Survey Division to investigate these classes in more detail.

It is realised that this system is unsuited for permanent use and should be replaced by a more comprehensive one for which we have an excellent example in the Land Capability Classification worked out by the U.S. Soil Conservation Service (Agricultural Handbook No. 61, 1954).

This Classification system has served as an example for many similar ones in other countries but needs modifying to serve local conditions.

4. THE U. S. LAND CAPABILITY CLASSIFICATION

A broad outline of the U.S. system is given in table 4. Land is classified at three levels, firstly in eight capability classes, secondly each class is subdivided into subclasses. At the lowest level of classification the subclasses are again subdivided into capability units.

The capability classes are set up in such a way that soils in Class I have the greatest alternative uses while those of Class VIII have the least possibilities for agriculture use. While the land capability class indicates the degree of limitation in land use, the subclass indicates the kind of limitation. For the latter grouping only four limitations are taken into consideration:

(e) runoff and risk of erosion
(w) wetness and need for drainage
(s) root zone and tillage limitations mainly connected with soil properties
(c) climatic limitations.

The lowest classification unit, the capability unit, groups individual kinds of soil on the following criteria:

1. Kinds and amounts of crops that can be grown successfully under a specified level of management
2. The ability of the soil to respond to management
3. Kind and amount of treatment required for soil conservation.

The capability unit should essentially be uniform in major characteristics.

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Table 3

Land suitability classification for Agriculture in Sarawak

CLASSES	DEFINITIONS	SUITABILITY FOR AGRICULTU
I	Flat to gently undulating terrain with slopes less than 5°.	Suitable for agriculture. Risk of flooding may exist.
II	Gently low-lying to moderately dissected hilly terrain with slopes less than 20° (including some hills less than 50 feet high with some slopes between 20 - 35°) Soil with no or few severe limitations.	Suitable for agriculture. But soil conservation measures needed on the steeper slopes.
III	Gently undulating to hilly terrain (slopes less than 20°) with soil with several severe limitations.	Marginally suitable for agriculture due to adverse soil factors. Expensive soil improvements needed.
IV	Strongly dissected terrain with slopes generally between 20-30°. Soil with no or few severe limitations.	Marginally suitable for agriculture owing to extreme danger of erosion. Very expensive soil conservation measures required.
V	Flat to gently undulating terrain with many severe soil limitations (mainly mangrove, nipah and peat swamp areas). Rugged country with slopes exceeding 35° in general; or with slopes of less than 35° occupied with soil with many severe limitations.	Not suitable for agriculture at present owing to adverse soil factors. Unsuitable for agriculture.

The classification above can be diagrammatically shown below:

Slope Class / Soil suitability	0° - 5°	5° - 20°	20° - 35°	over 35°
A	SUITABLE			
B	SUITABLE			
C	MARGINAL			
D	UNSUITABLE			

Soil Suitable Classes:

A. No severe soil limitations

B. Few severe soil limitations

C. Several severe soil limitations

D. Many severe soil limitations.

The main soil limitations a

a) fertility; b) rootin

c) salinity; d) flood

e) susceptibility to erosio

The factors used for arriving at a capability rating in this scheme are, except for the climate, collected in the field. In order to be able to judge the value of these factors with a view to local conditions the full range according to the U.S. Soil Conservation Handbook No.61 is given:

a. Effective depth of soil (as depth over rock, tough clay or hardpan)

Very deep	60 inches or more
Deep	36 - 60 inches
moderately deep	20 - 36 inches
shallow	10 - 20 inches
very shallow	0 - 10 inches

b. Texture of surface soil (fineness of consistuent particles)

Very heavy	- heavy clay - (60 per cent or more 2-micron clay particles)
Heavy	- clay, silty clay, sandy clay
Moderately heavy	- silty clay loam, clay loam, sandy clay loam
Medium	- silt loam, loam, very fine sandy loam
Moderately light	- sandy loam, fine sandy loam
Light	- loamy fine sand, loam sand
Very light	- sand, coarse sand.

c. Permeability of subsoil

Very slow	- less than 0.05 inch of water percolation per hour
Slow	- 0.5 to 0.20
Moderately slow	- 0.20 to 0.80
Moderate	- 0.80 to 2.50
Moderately rapid	- 2.50 to 5.00
Rapid	- 5.00 to 10.00
Very rapid	- 10.00 or more

d. Permeability of substratum

Very slow	- less than 0.05 inch of water percolation per hour
Slow	- 0.05 to 0.20
Moderately slow	- 0.20 to 0.80
Moderate	- 0.80 to 2 50
Moderately rapid	- 2.50 to 5.00
Rapid	- 5.00 to 10.00
Very rapid	- 10.00 or more

e. Thickness of surface soil

Thin	- 0.6 inches
Moderately thick	- 6 to 12
Thick	- 12 to 24
Very thick	- 24 to 36

f. Available moisture capacity (inches of absorbed water per 60 inches of soil depth)

Very high	- 12 inches or more
High	- 9 to 12
Moderate	- 6 to 9
Low	- 3 to 6
Very low	- less than 3

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Land use suitability (broad grouping)	Land-capability class (degree of limitations for use)	Land-capability subclass (grouped according to kind of limitations; shows examples only)	Land-capability unit (land management groups based on physical characteristics; shows examples only)
Suited for Cultivation	I Few limitations. Wide latitude for use. Very good land. (Green on coloured map) II Moderate limitations in use. Good land (Yellow) III Severe limitations in use. Regular cultivation possible if hazards are provided against Moderately good land. (Red) IV Very severe limitations in use Suited for occasional cultivation or for some kind of limited cultivation. (Blue)	e Use is limited by moderate hazards of water or wind erosion c Climate Use is limited by excess water drainage needed for cultivation s Use is limited by low water-holding capacity or by low plant-nutrient content	Moderately sloping, slightly acid soils on limestone. Moderately sloping, high acid soils on sandstone or shale. Imperfectly drained acid soils. Poorly drained neutral soils. Sandy, rapidly permeable soils.
Not suited for cultivation.	V Not suited for cultivation because of wetness, stoniness, overflows, etc. Few limitations on use for grazing or forestry. (Dark green) VI Too steep, stony, dry, wet, etc., for cultivation. Moderate limitations on use for grazing or forestry. (Orange) VII Very steep, rough, dry, wet, etc. Severe limitations on use for grazing or forestry. (Brown) VIII Extremely rough, dry, swampy, etc. Not suited for cultivation, grazing or forestry Suited for wildlife, watershed protection, or recreation. (Purple)	Grouping of sites according to kind of limitation	Sites significant in management of ranges, pastures, forests, etc.

g. Reaction

Acid	- 6.5 pH or less
neutral	- 6.6 to 7.3 pH
alkaline	- 7.4 pH or more

h. Natural soil drainage

Well drained	- well oxidized and free from mottling of colours in surface and subsoil.
moderately well drained	- well oxidized and free from mottling except in lower part of subsoil.
imperfectly drained or somewhat poorly drained.	- well oxidized surface, subsoil mottled.
poorly drained	- gray colour, mottling in surface and subsoil
very poorly drained	- dark surface soil and gray or mottled subsoil.

i. Inherent fertility

High
Moderate
Low
Very low

j. Organic Content

High
Medium
Low

k. Slope

Nearly level
Gently sloping
Moderately sloping
Strongly sloping
Steep
Very steep

l. Erosion

No apparent or slight
Moderate
Severe
Very severe
Very severely gullied land

m. Wetness

Slightly wet	- growth of crops slightly affected or planting dates delayed for brief periods, as less than a week
Moderately wet	- growth of crops moderately affected or planting dates delayed by a week or so
Very wet	- growth of crops seriously affected, or planting delayed as much as a month or more
Extremely wet	- swamp, marsh, too wet for cultivated crops or improved pastures.

n. Salinity

Slight	- crops yields slightly affected or range of crops slightly limited
Moderate	- crops yields moderately affected, or range of crops moderately limited
Severe	- crop yields seriously affected, or range of crops severely restricted
Very severe	- growth of useful vegetation prohibited except some salt-tolerant forms.

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c. Frequency of overflow

Occasional overflows or overflows of short duration	- crops occasionally damaged, or planting dates delayed;
Frequent damaging overflows or overflows of long duration	- crops frequently damaged, or range of crops limited
Very frequent overflows, or overflows of very long duration.	not feasible for cultivated crops

5. DISCUSSION OF BASIC PRINCIPLES FOR MODIFYING THE UNITED STATES LAND CAPABILITY SYSTEM.

1. Classes - In analysing the system outlined in the previous section a few major characteristics become apparent, namely:

a. It is mainly geared at classifying land for the cultivation of annual crops and soil factors are evaluated on this assumption.

b. The degree of limitation is classified with a view to mechanised farming and United States soil conservation requirements in relation to the climatic range within the United States.

To modify this system, considerable thought must therefore be given firstly to the types of cultivation of major importance in this region and secondly to our crops and soil requirements thereof and thirdly to the local climate in relation to soil conservation.

It is suggested

that since tree crops form a major part of the crops grown here there should not be 4 classes for Land unsuitable for agriculture,
that a division into 7 classes is sufficient to suit local condition,
that the interpretation of the definitions should be geared to express suitability to local cultivation systems,
that the degree of limitation should be rated with a view to local climatic conditions and crops normally grown in this region.

In order to achieve this the classifying factors listed in the foregoing section should first be evaluated for local conditions.

The following modifications are therefore suggested:

a. Effective depth of soil

To retain the subdivisions, but to keep in mind that tough clay is not a limitation in growing rubber.

b. Texture of surface soil

To replace this by a system taking the texture range of the whole profile into account since this is important for tree crops. Also surface textures vary widely over small areas in Sarawak.

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c. Permeability of subsoil

To omit. This information is impossible to collect without detailed work and special equipment.

d. Permeability of saturations

To omit for reasons given under c.

e. Thickness of surface soil

To omit. See 'b'

f. Available moisture capacity

To omit, since it is impossible to collect this data without detailed work and it is not regarded as essential data in the Sarawak climate.

g. Reaction

To insert more groups in the acid range and the groups should be redefined considering that most tropical soils are acid. Suggested groups are:

Alkaline pH	7
Neutral pH	6 - 7
Weakly acid	6 - 5
Acid	5 - 4
Strongly acid	4

(pH concerns topsoils).

h. Natural soil drainage

To retain in full

i. Inherent fertility

To retain; but subdivisions should be based on C.E.C , base saturation, P value, and mineral reserve. Satisfactory grouping has to await more results from agronomy work since the exact relation between those factors and actual crop response is at present not known.

j. Organic content

To omit, since this is under local conditions of a non-permanent nature. To be substituted by:

Depth of organic horizons (35% loss on ignition)

Shallow	- 0 to 10 inches
moderately deep	- 10 to 40 inches
deep	- more than 40 inches

k. Slope

To be retained but the following definitions are suggested

Nearly level	- 0 to 2°	Strongly sloping	- 10 to 15°
Gently sloping	- 2 to 5°	Steep	- 15 to 25°
Moderately sloping	- 5 to 10°	Very steep	- over 25°

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l. Erosion

To be retained but classes need re-definition to suit local erosion hazards in relation to climate. Suggested divisions are:

1. Non gullied
2. Slight - few, shallow gullies, stable slopes
3. Moderate - few deep gullies, few landslides, - moderately stable slopes
4. Severe - many deep gullies, landslides common, unstable slopes
5. Very severe - severely gullied land, many landslides, very unstable slopes.

m. Wetness

To be replaced by the following suggested division

1. Slightly wet - topsoil at saturation point only immediately after rain.
2. Moderately wet - topsoil at saturation point for some period after rain.
3. Wet - topsoil at saturation point throughout wet season.
4. Very wet - topsoil at saturation point for most of the year.
5. Extremely wet - submerged for most of the year.

n. Salinity

To be maintained with a change in definition of classes. Emphasis should be on Exchangeable Sodium and soluble Sodium content but at present in Sarawak electric conductivity of groundwater is the only practical means of measuring salinity. With this in mind, suggested classes are:

Non saline	- groundwater below 500 micromhos/cm at 25°C.
Weakly saline	- groundwater 500-4,000 micromhos/cm at 25°C, in dry season. Below 500 in wet season.
Moderately saline	- groundwater 500-4,000 micromhos/cm at 25°C, throughout the year.
Strongly saline	- groundwater 500-4,000 micromhos/cm at 25°C. during wet season, 4,000 in dry season.
Severely saline	- 4,000 micromhos/cm at 25°C. throughout the year.

o. Frequency of overflow

To be retained but called 'liability to flooding' and with a change in definition of classes. Suggested classes are:

1. Non-flooded
2. Occasional floods of short duration
3. Frequent floods of short duration
4. Occasional floods of long duration
5. Frequent floods of long duration

It is further suggested that the factor 'climate' should be abolished. In the United States Land Capability Classification this factor is regarded as important in relation to erosion hazard and land conservation measures but from this viewpoint climate is uniform for most areas in Sarawak. This factor should however be considered in selecting specific crops at high altitudes in a possible recommended Land Use Classification.

To suit local purposes, the sixteen classification factors of the United States' system can therefore be reduced to eleven.

In using these factors for placing soil units in the capability classes two considerations are of major importance. Firstly Klingebiel (1958, p.161) in analysing capability groupings in the United States recognizes the fact that differences in management or yields of perennial crops may be greater between soils within one class than between classes. In Sarawak this should be avoided as much as possible since tree crops are here more important than annuals. Secondly Klingebiel (op.cit.p.161) states that in the United States only the continuing limitations are classified meaning that where it is feasible to remove non-continuing limitations such as water, stones, excess salts etc., they are not being considered in the capability ratings. The removal of these non-continuing limitations are quite important in Sarawak from an economic point of view and it would be unrealistic not to consider them. Since we can normally not judge whether amelioration is within economic means it is suggested that in all cases Land should be classified on its present state.

Little attention has been given to the importance of chemical fertility in the United States, presumably because it is considered to be a non-continuing limitation which can be easily altered by fertilization. Factors related to response of fertilizer treatment are regarded as more important. This was also recognised by Baeyens (1959, p.102) who in connection with the evaluation of tropical soils in Central Africa considers that the chemical characteristics of a soil are least important since a soil under a favourable climate and possessing optimal physical and hydrological value is fertile, even when its percentage content of nutritive material is low. This may be open to question but the author is of the opinion that this can in general be confirmed by the behaviour of soils in Sarawak.

After taking into account these considerations it is possible to show in a diagrammatic form the minimum requirements of the capability classes distinguished in the modified scheme.

Table 5 gives the framework of a possible Sarawak Land Capability Classification. The classifying factors have been arranged in a suggested order of importance so that it may be possible to place a soil with some certainty even when classifying factors of minor importance are lacking. The Table does not indicate the maximum requirements so that soils placed for instance in class III can have better properties than noted but for the one limitation, the minimum requirement. The nature of the limitation is indicated by a symbol at the subclass level so that it is possible to judge whether the Land can be raised to a higher class if the limiting factor is remedied.

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Table 5.

Suggested Grouping of classifying factors

	Capability Class	Classifying factors										
		Slope	Erosion	Effective depth of soil	Natural Soil drainage	Wetness	Salinity	Flooding	Textures of soil profiles	Depth of organic horizon	Inherent fertility	Reaction
suitable for agriculture	Class I	gently sloping	none*	deep	well drained	slightly wet	none	no floods	moderately heavy to moderately light	shallow	?	weakly acid
	Class II	moderately sloping	slight	moderately deep	moderately well drained	moderately wet	weak	occasional of short duration	heavy to light	shallow	?	acid
	Class III	strongly sloping	moderate	moderately deep	poorly drained	wet	moderate	frequent of short duration	very heavy to light	moderately deep	?	acid
	Class IV	steep	severe	shallow	very poorly drained	very wet	strong	occasional floods of long duration	very heavy to very light	moderately deep	?	strongly acid
unsuitable for agriculture	Class V	-	-		Very poorly drained	extremely wet	severe	frequent floods of long duration	very heavy to very light	deep	-	-
	Class VI	very steep	very severe	shallow	-	-	-	-	very heavy to very light	-	-	-
	Class VII	very steep	very severe	very shallow	-	-	-	-	very light to very heavy	-	-	-

? requires definition.

Following the definition of classes V to VII suggested by Klingebiel et al (1961, p.9) Class V land is mainly excessively wet land unfit for normal crop production, while classes VI and VII consist of extremely steep land. Definitions of the classes are for the present not suggested since the system should first be tried out for a number of areas so that attention can be given to all implications in the phrasing of the definitions.

2. Subclasses and units

The four subclasses indicate the degree of limitation. It is thought however that four subclasses are insufficient to give a correct indication of the limitation involved. There is a great difference between soil wetness due to bad internal drainage and wetness due to flooding, and it is difficult to indicate in the given subclass what limitation is really involved. Haantjens (1962, p.6,) in a modified version of this classification system for Australian New Guinea and Papua suggests a subdivision of the symbol 's' (soil limitation) into s_2 for inadequate moisture due to shallow profile of coarse texture and s_3 for poor drainage due to slow permeability while he adds subclasses 'd' for wetness due to a high watertable and f for wetness due to overflow. He also discards the American practise of assigning only one subclass symbol to any type of land and uses two or three symbols of necessary. It is likely that for Sarawak conditions a similar modification has to be adopted especially since not all soil limitations are of equal importance. The danger is that the number of subclasses become unmanagable and this must be avoided.

The fact is recognised that in the United States this difficulty is overcome by subdividing the subclasses into capability units at the third level of classification. It is however suggested that in Sarawak at this stage no units can be distinguished since this final subdivision is based on a considerable amount of managerial experience and research which is not available in Sarawak. The increase in the number of subclasses is therefore a logical consequence of omitting the units from this scheme.

Finally it should be realised that it is not possible to collect all the required information for a Land Capability map on a reconnaissance soil survey. In Sarawak these are based on a scale 1:50,000 to 1:100,000. The Bureau of Reclamation Manual (1953, 2/6/1) states that in the United States Land Capability Maps of a reconnaissance nature are on a mapping scale of 1:24,000 which is considered appropriate to semi-detailed soil mapping in Sarawak. A reconnaissance capability map can quite likely be complied from a semi-detailed soil map.

VI. CONCLUSION

It is suggested that the establishment of a Land Capability Classification of the nature proposed and its application under present conditions in Sarawak is feasable and that development planning may benefit from it since such a classification gives in objective terms the relative value of each land type over the whole of Sarawak. As it is assumed that a detailed system of this nature has not yet been prepared in the other States of Malaysia it is suggested that where the fusion of soil classifications used in the various States may fail because of the natural emphasis on local conditions in such classifications, a Land Capability classification for the whole of Malaysia may have more chance of success since such a classification would be based on inherent land characteristics which are essentially the same throughout the country.

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REFERENCES

1. BAEYENS, J. The bases of Classification of Tropical Soils in relation to their agricultural value, Proc. 1st Comm. Conf. on Tropical and sub Tropical Soils., C.A.B. Technical Communication No.46, Harpenden, 1949.

2. SOIL SURVEY STAFF, Bureau of Plant Industry, Soils and Agricultural Engineering. Soil Survey Manual. U.S. Dept. of Agriculture Handbook No.18, Washington D.C. 1951.

3. LEWIS, A.B. Land Classification for Agricultural Department; F.A.O. Development Paper No.18, Rome, 1952.

4. U.S. DEPARTMENT OF INTERIOR: Bureau of Reclamation Manual, Vol. 5. Land Classification Handbook, Washington D.C. 1953.

5. U.S. DEPARTMENT OF AGRICULTURE, Soil Conservation Service. A Manual on Conservation of Soil and Water, Agricultural Handbook No.61, Washington D.C 1954.

6. Sarawak Map Series No.10, Land Use of Sarawak, published by Land and Survey Department, Sarawak, 1956.

7. KLINGEBIEL, A.A. Soil Survey Interpretation - Capability Groupings. Soil Sci. Soc. Amer. Proc. 22:160-163, 1958.

8. KLINGEBIEL, A.A. and P.H. MONTGOMERYG. Land Capability Classification, Agricultural Handbook No.210, U.S. Conservation Service. Dept. of Agriculture, Washington D.C.1961

9. HAANTJENS, H.A. Land Capability Classification for Regional Planning in Intergrated Surveys in Australian New Guinea. Unpublished typescript paper, Division of Land Research and Regional Survey, C.S.I.R.O. Canberra, 1962.

10 VINK, A.P.A., Planning of Soil Surveys in Land Development, Veenman and Sons, Ltd., Wageningen, 1963.

11. J.P. ANDRIESSE Report on semi-detailed soil survey of proposed Penrissen Land Development Area - Soil Survey Report No.44/2, unpublished. Dept. of Agriculture, Kuching, 1965.

12. Soil Survey Staff, Sarawak. Soil Classification of Sarawak (in preparation), Dept. of Agriculture Kuching, 1965.

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APPENDIX TO PAPER ON "THE CLASSIFICATION AND EVALUATION OF LAND IN SARAWAK"

After the completion of this paper the capability classification discussed therein was tried out in a 750 sq. miles large area surveyed at a reconnaissance level.

Although the proposed system is normally not intended for use in reconnaissance mapping this exercise was aimed to find out to what extent the proposed classification is applicable in reconnaissance surveys.

For this purpose 10 subclasses were adopted, one for each classifying factor. By using subclasses this way it is possible to show on the map the reason why a certain parcel of land is given a certain capability class rating.

Table 5 in the paper was modified and extended as shown in table 6 attached to this appendix.

For the 10 subclasses the following symbols were chosen:-

Classifying factors	Symbol
slope/erosion	t
depth of soil	d
soil drainage	sd
wetness	w
salinity	sa
flooding	f
texture	tx
depth organic horizon	o
inherent fertility	n

The two classifying factors slope and erosion were combined since they are intimately related to each other. The limitation "reaction" has been omitted from the subclasses since it is connected with inherent fertility.

Distinction between non-continuing limitations (classifying factors) and permanent limitations was made by underlining the symbols of the non-continuing limitations so that from the capability map it is possible to deduct what type of land can be improved and subsequently raised to a higher capability.

It appeared that most soil mapping units, in this case soil families as distinguished in Sarawak, could be placed in the 7 capability classes on account of soil characteristics only. The rating was normally already low on account of such features and for many families unknown features such as risk of flooding and severity of salinity did not need to be taken into consideration at all. Contoured maps were a great help in indicating the slope class of the mapping units.

Table 7 lists the capability rating of the mapping units. Particulars of the soil families can be found in the "A Classification of Sarawak Soils" prepared by the Soil Survey Staff and which is also the subject of a paper to this conference. From this list it can be noticed that certain subclasses have two limitations which are both responsible for the rating of the mapping unit in the indicated class.

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TABLE 6

Capability Class	Slope (t)	Erosion	Effective depth of soil (d)	Natural soil drainage (sd)	Wetness (w)	Salinity (sa)	Flooding (f)	Textures of soil Profiles (tx)	Depth of organic horizon (o)	Inherent fertility (n)*	Reaction (r)
	Classfying Factors										
Class I	gently sloping 0-5°	none*	deep > 36"	well drained	slightly wet	none	no floods	moderately heavy to moderately light	shallow 0-10"	moderate	weakly acid
Class II	moderately sloping 10°	slight	moderately deep 30 - 36"	moderately well drained	moderately wet	weak	occasional of short duration	heavy to light	shallow 0-10"		acid
Class III	strongly sloping 10-15°	moderate		poorly drained	wet	moderate	frequent of short duration	very heavy to light	moderately deep 10" - 40"	low	
Class IV	steep 15 - 25°	severe	shallow 10 - 20"	very poorly drained	very wet	strong	occasional floods of long duration	very heavy to very light		very low	strongly acid
Class V	-	-	-		extremely wet	severe	frequent floods of long duration		deep >40"	-	-
Class VI	very	very	shallow 10-20"	-	-	-	-		-	extremely low	-
Class VII	steep 25°	severe	very shallow 10"	-	-	-	-		-	-	-

* based on crop behaviour, non-fertilised; no defined, arbitrary limits have been chosen.

In case one of the limitations is non-continuing and the other is permanent it can be deducted from the map that even after amelioration the land will remain in the given capability class. If both factors are non-continuing then after amelioration the capability can be raised to a higher class.

The difficulties experienced in trying out the system for a reconnaissance system were mainly cartographic ones. Many associations of capability classes and subclasses occur since in reconnaissance surveys associations of families are the main mapping units. It is, therefore, physically impossible to show all variations clearly on a small scale map.

Apart from these cartographic difficulties not enough information was available on intensity of flooding in certain areas, and severity of salinity for others.

Finally, an attempt was made to define the 7 land classes as shown in table 8.

It can be concluded that if proper contoured topographic maps are available and the soil pattern is not too complex a fairly accurate capability map can be prepared from data collected in a reconnaissance survey of the nature adopted for Sarawak.

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TABLE 7

CAPABILITY RATING OF THE SOIL FAMILIES

OCCURRING IN THE TRIAL AREA

Classes and subclasses	soil families
Class I.	not present in trial area.
Class II.t	Tarat-some
Class II.f	Malang-some, Ramun-all
Class III.t	Tarat, Abok
Class III.d	Sedong and Kapit-some
Class III.sd	Bijat-all, Plan-some
Class III.sd.sa	Pendam and Nonok-all
Class III.f	Malang-some, Seduau-all, Kayan-some
Class III.tx	Semilajau-all
Class III.n	Sabangan-all
Class III.n.t.	Merit, Bekenu, Nyalau-some
Class IV.t	Tarat, Sedong, Abok, Nyalau, Merit, Bekenu, Kapit
Class IV.sd	Sebandi-all
Class IV.sd.sa	Rajang and Belat-some
Class IV.sd.o	Mukah and Igan-all
Class IV.sd.tx	Tatau-all, Plan-some
Class IV.sd.n	Embang and Gong-all
Class IV.w.n.	Lubai and Triboh-all
Class IV.tx	Kabong and Sematan-all
Class IV.tx.f	Kayan-some
Class IV.tx.n	Jerijeh-all
Class IV.n	Saratok, Kerait and Matang-all
Class V.sa	Rajang and Belat-some
Class V.sa.o	Limbang-all
Class V.o.sd	Anderson-all
Class VI.t	Tarat, Sedong, Kapit, Abok, Nyalau, Merit, Bekenu, Matang, Saratok-some
Class VI.n	Miri and Bako-all
Class VI.d.n.	Gaya-all
Class VII.d	Meluan-all

TABLE 8.

LAND CAPABILITY CLASSES

Class I land	- Land with no specific problems other than low fertility which can be remedied easily. It is suitable for a wide range of shallow and deep-rooting crops both annuals and perennials.
Class II land	- Land with no problems other than a slight risk of flooding, or slightly saline conditions with imperfect drainage, both of which can be easily remedied. Low fertility may be a problem in some areas. It is suitable for most annual and perennials crops.
Class III land	- 1. Land in which the crop range is restricted because of poor drainage, moderately saline conditions or a moderate risk of flooding. 2. Land which demands moderate conservation measures and which is mainly suitable for perennials only. Generally both land types are of low fertility.
Class IV land	- 1. Land in which the crop range is severely restricted because of very poor drainage, strongly saline conditions or a severe risk of flooding. 2. Land which requires intensive conservation measures, such as terracing, and which is only suitable for perennials. 3. Land with very low fertility.
Class V land	- Land which is excessively wet, or severely saline, or in which a severe risk of flooding exists. It is only suitable for crops with a high tolerance to these conditions.
Class VI land	- 1. Very steep land with a shallow soil cover, unsuitable for normal agriculture. It is only suitable for some perennials with intensive conservation measures. 2. Land with extremely low fertility, unsuitable for normal crop production.
Class VII land	- Land which is very steep and with a very shallow soil cover, not suitable for any form of cultivation.

DISCUSSION

Smallwood: - Do you not consider the "natural or inherent" fertility an important factor as this bears strongly on the "cost" of production once this land is brought into production?

Andriesse: - Inherent fertility is important but terrain and drainage in this climate are more important and 'cost of production' being an economic factor is not being considered as a classification factor since it is not a continuing limitation.

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Dumanski: - What are the mechanics by which your families are put into the various classes? Is it an Index method? Are the classifying factors all of equal importance, as they would have to be if the condemnation method were to be used effectively?

Andriesse: - In the final assessment a soil is given a capability class according to the lowest denominator of the classifying factors as given in table 6 and these are shown by symbols after the capability class e.g. Bijat Family is placed in capability class III sd because the lowest classifying factor is poor drainage but on improvement of the drainage status of this soil it can be elevated to a higher capability class.

Bailey: - I would like to suggest that slope is not a continuing limitation in that it can be modified by machinery, terracing, etc.

Andriesse: - Slope may be corrected permanently in very few cases but in general it is a continuing limitation even with terracing.

Ives: - The large number of Capability Sub-Classes (potentially) hardly seems to be a simplification of the soils map - which a Capability Classification should be!

Andriesse: - The subclasses have been set up especially for large scale maps based on semi-detailed soil surveys. I am inclined to agree that the number of capability classes should be reduced to five but we are as yet not certain how the classifying factors are to be joined.

SOIL SUITABILITY CLASSIFICATION FOR DRYLAND CROPS IN MALAYA

by

IGNATIUS WONG

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INTRODUCTION

The need for a soil suitability classification of Malayan soils has been recognised a long time ago; but it was not until 1965 that a major attempt was made. This was due partly to the need to incorporate soil resource data in the Land Capability Classification Exercise organised by the Technical Sub-Committee of the Economic Planning Unit of the Prime Minister's Department. At the same time it was gauged that the knowledge of Malayan soils gained by means of the Reconnaissance Soil Survey Programme would be sufficient for a first attempt at classifying the Malayan soils according to their suitability for the various economic dry-land crops.

CLASSIFICATION

Of all the possible methods of soil suitability classification, that which is based on the limitations to agricultural development has been found to be most practicable under Malayan conditions.

Emphasis has been laid, in setting up this classification, on the knowledge of field conditions and the behaviour of the soils under various management practices because Malayan soils are generally low in nutrients and, without exception, have to be fertilized in order to sustain high yields. All available laboratory data have, nevertheless, also been utilised including information on trace elements as experience has shown that certain Malayan soils are deficient in trace elements besides the major elements.

The criteria used in the setting up of the soil suitability classification have been separated into three groups, namely:-

(a) Very Serious Limitations.

(b) Serious Limitations.

(c) Minor Limitations.

(a) Very Serious Limitations

These are limitations which are very difficult to remove or can only be overcome at prohibitive or uneconomic cost. They are:-

(1) Slopes steeper than 20°.

(2) Massive, thick laterite at or very close to the surface.

(3) Extreme rockiness i.e. boulders and rocks almost entirely covering the surface.

(4) Land disturbed by mining activities.

(5) Toxicity caused by extremely high contents of certain elements.

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(b) Serious Limitations

These limitations can be overcome by a high standard of management. They are:-

(1) Acute nutrient deficiencies.
(2) Very poor and poor drainage.
(3) Moderately steep slopes (12^o - 20^o).
(4) Massive, thick laterite within 2 feet of the surface.
(5) 2 feet or more of acid peat.
(6) Strong compaction.
(7) Sand texture throughout.
(8) Acid sulphate conditions.
(9) Saline conditions.

(c) Minor Limitations

These limitations do not impede root ramification or prevent the uptake of nutrient seriously. They are:-

(1) Susceptibility to flooding.
(2) Weak structures within the top 4 feet.
(3) Imperfect or moderate drainage.
(4) Slightly steep slopes ($6 - 12^o$)
(5) Massive, thick laterite between 2 and 3 feet from the surface.
(6) Acid peat less than 2 feet thick.
(7) Weak or moderate compaction.

Based on the above groups of criteria, the following five soils suitability classes have been established:-

Class 1.

The soils in Class 1 do not have any limitation to agricultural development. They are suitable for a wide range of crops.

Class 2.

Class 2 soils have one or more minor limitations to agricultural development and because of this they are not suitable for as wide a range of crops as Class 1 soils.

Class 3.

In class 3 are soils with at least one serious limitation to agricultural development. These soils can only be economically exploited if they are cultivated with more tolerant crops such as rubber.

Class 4.

The soils in Class 4 have more than one serious limitation to agricultural development. They can be cultivated profitably when a very high standard of management is available.

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lass 5.

Class 5 soils have at least one very serious limitation to ricultural development, and because of this they are best allowed to tinue under forest or to regenerate under a new forest.

A classification of the more commonly occurring soils of Malaya given in table 1.

SPECIFIC CROP CLASSIFICATION

As the scheme outlined above is meant to apply to as wide a range dryland crops as possible, certain soils have had to be downgraded in er to fit into the classification. For example, the limestone soils ong to the Langkawi and Kaki Bukit Series have deep profiles, clay tures, friable consistencies, moderate to strongly developed structures d good drainage; yet they have been placed in Class 3 because present ience indicates that rubber does not yield well on these soils and ir suitability for oil palm has yet to be tested. On the other hand, y are the best soils for citrus.

Thus, when considering the suitability of soils for specific crops, erience has shown that it is necessary to reassess the various itations to agricultural development in the light of the requirements each particular crop. An example for oil palm is given in table 2. this exercise it has been found that the classification of the soils o three suitability classes is adequate.

The same exercise could be carried out for the other crops too and it l become evident that the suitability range of each limiting factor vary from crop to crop. For sugarcane, for example, slopes in excess 6° would be a serious limitation. On the other hand, this would hardly a minor limitation for rubber.

Nevertheless, both the schemes presented here have their merits. general classification because of its comprehensive nature has wide lication while the specific classification, in having more specific s of reference, exploits the full potentiality of each soil for a ticular crop.

DISCUSSION

iesse: - Are depth phases mapped in the Malacca series since it falls into two suitability classes.

g: - Yes, depth phase are mapped in the field.

on: - What is a definition of rockiness as a criterion for soil suitability classification.

r: - 'Rockiness' means rock outcrops on the surface. We are looking into the possibility of using the American system of assessing rockiness.

lwood: - If the American Land Classification is adopted one must bear in mind that "rocks or stoniess" is considered a limitation to mechanical cultivation, which isn't so important a factor when one is practising tropical agriculture.

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Type of Impediment	Suitability Classes		
	Suitable	Marginal	Unsuitable
Topography	0^{o} - 12^{o} slopes	12^{o} - 20^{o} slopes	20^{o}+ slopes
Impenetrable layer	4 + ft. below the surface	2 - 4 ft. below the surfae	0 - 2 ft. below the surface
Compact layer	4 + ft. below the surface	2 - 4 ft. below the surface	0 - 2 ft. below the surface
Rockiness	0 - 25%	25 - 50%	50% +
Drainage	(a) Imperfectly to well drained (b) Gley horizon 3 ft. or more below the surface.	(a) Poorly drained (b) Gley horizon 1 - 3 ft. below the surface.	(a) Very well drained to excessively drained. (b) Gley horizon 1 ft. or less below the surface.
Texture	Clay to loam (0 - 43% sand)	Sandy loam (43 - 70% sand)	Loamy sand to sand (70 - 100% sand).
Toxicity	None to slight	Moderate	High
Acid Sulphate Conditions	None to slight	Moderate	High
Salinity	None to slight	Moderate	High
Peat	0 - 2 ft. thick	2 - 4 ft. thick	4 + ft. thick

Table 1.

THE SOIL SUITABILITY CLASSIFICATION OF COMMON MALAYAN SOILS

Class 1	Class 2	Class 3	Class 4	Class 5
Rengam	Yong Peng	Rengam (12^{o} + slopes)	Bukit Tuku	Bukit Temiang
Jerangau	Batang Merbau	Jerangau (12^{o} + slopes)	Kg.Cherang Hangus	Bukit Ajil
Kampong Kolam	Patang	Tampin	Lati	Malacca (laterite shallower than 2ft.)
Segamat	Kuala Brang	Bukit Lunchu	Padang Gong Chenak	
Kuantan	Batu Lapan	Kodiang	Kg. Lubok Kiat	Pohoi (steep slopes)
Munchong	Kemuning	Langkawi	Kg. Pusu	Kuala Brang (steep slopes)
Serdang	Kuala Nerang	Kaki Bukit	Rudua	
Selangor (drained)	Telega	Masai	Jambu	Kedah (steep slopes)
Kangkong (drained)	Telemong)	Kulai	Penor	Batang Merbau (steep slopes)
	Akob	Kedah (slopes less than 20^{o})	Rusila	Bungor (steep slopes)
	Briah	Batang Merbau	Kranji	Steepland
	Sitiawan	Seremban	Linau	Disturbed land.
	Pohoi	Malacca	Kampong Telok	
		Gajah Mati	Medium to Deep Peat (more than 2 feet thick)	
		Changloon		
		Pokok Sena		

Class 1	Class 2	Class 3	Class 4	Class 5
		Durian		
		Batu Anam		
		Apek		
		Marang		
		Bungor		
		Selangor (undrained)		
		Kangkong (")		
		Holyrood		
		Sungai Buloh		
		Manik		
		Sogomana		
		Rasau		
		Harimau		
		Ulu Tiram		
		Tampoi		
		Shallow Peat (less than two feet thick)		
		Organic Clays and mucks		
		Local Alluvium		
		Colluvium		

Bailey: - Would not "lack of water in the dry season" rather than "sand texture throughout" be a better way of expressing this serious Limitation.

Wong: - Periodic drought is not the only condition implied in the term used; very poor nutrient retentive power is also another condition implied.

Blanker: - I quite agree with Mr. Andriesse in not relating land classification with any specific crop e.g. is enough known about the moisture requirement for oil palm.

Wong: - In the soil suitability classification for oil palm presented here, only the soil requirements are considered. It is fully borne in mind that the factor of climate, particularly the amount and distribution of rainfall, can override the soil suitability assessment of any crop.

Ng: - The soil suitability classification of Malaya has been set up principally to satisfy the requirements of the country for agricultural diversification whereas the classification proposed by Mr. Andriesse is of a more academic nature.

Thomas: - Working as a practical pedologist, one finds that on submitting a Land Use Recommendations Map showing a complicated array of Land Classes and sub-classes, coined in general terms, the layman, who is usually only concerned with a specific problem, inevitably asks - what crop should we grow on that particular land. I therefore, do not think that any academic approach to this type of classification, at this stage of development in each of our States is of great practical importance.

Pushparajah: - You consider susceptibility to flooding as a minor limitation, but don't you think that more emphasis is required for this point since it has been observed that retardation of growth of rubber trees is associated with waterlogged soils.

Wong: - This condition is a minor limitation because it applies to soils situated close to the larger rivers which are subject to periodic flooding. It does not refer to an impedence of drainage in a soil.

GENERAL DISCUSSION

Smallwood: - In the Malayan soil suitability scheme acute nutrient deficiency is a serious limitation while Mr. Andriesse in his proposed classification does not consider this as a serious limitation at all.

Andriesse: - I do not consider that the low nutrient status of a soil is a serious limitation because it can be corrected by fertilizer application. This is more an economic factor than a soil factor. I think that continuing limitations should be used as classifying factors while factors that can be altered by management should not be considered at all.

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Bailey: - I think this is a case for taking each problem on its merits, using basic data that is as objective as possible.

Dumanski: - I don't see how the objectivity or durability of the Sarawak system is any more than that in Malaya in the light that new technology and personnel will view the factors in a different light.

Smallwood: - The Sarawak system is modeled on the American system but it is not complete unless the soil index is also included, for failing that the Sarawak system would have only the philosophy of the American system but not the mechanics to go with it.

Scott: - Either system would be very useful to help standardise our recommendations and make them more objective. They should not however be for general consumption. Administrators already have difficulty in understanding our reports and we would cause confusion rather than solve problems by attempting to couch our recommendations in these terms. The classifications adopted is best kept for internal use only.

Chairman: - There is no doubt a fair bit of disagreement in the methods of classification but I think basically there is a sameness of approach in the scheme suggested. They differ at the level of comprehensiveness - some are too simple while some are too comprehensive. There is room for both of these approaches which are interlinked. The question of how much of the system we reveal to the eventual users is an important one because obviously they can be confused if we reveal too much to them.

Session D. - Soil Fertility and Plant Nutrition

Chairman: Ng Siew Kee

(1) "A New Technique of Evaluating Phosphate Fertility in Soils" by Y.T. Shao.

(2) "Content of Major Nutrients in Rubber-Growing Soils of Malaya" by M.M. Guha and Yeow Kheng Hoe.

(3) "Chemical and Agronomical Studies of a Common Upland Soil in Sarawak" by J.M. Bailey.

Chairman: Shao Yen Tze

(4) "The Effect of Soil and Fertilizers on the Yield of Rice and the Chemical Composition of the Rice Leaves" by J.M. Bailey

(5) "Prospects of Plant and Soil Analysis in Assessing the Fertilizer Requirements of the Oil Palm in Malaya" by Ng Siew Kee and S. Thamboo.

(6) "Responses to Fertilizers in Heavea Brasiliensis in relation to Soil Characteristics" by M.M. Guha and E. Pushparajah.

A NEW TECHNIQUE OF EVALUATING PHOSPHATE FERTILITY IN SOILS

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Introduction

The estimation of available phosphate in soil by chemical extractants is essentially empirical and the amount of phosphorous removed from soil will depend largely on factors such as nature of extractant, the extraction time and the pH of the extracting solution.

Breland and Sierra (1962) compared the amounts of phosphorus removed from different soils by various extractants. Eight extractants listed hereunder were selected on the basis of extensiveness of use and ranged from water to those containing strong acid,

(i) 0.025 N HCl and 0.03 N NH_4F (Bray and Kurtz (1945)).
(ii) 0.05 N HCl and 0.025 N H_2SO_4 (Mehlich (1953)).
(iii) 0.5 N $NaHCO_3$, pH 8.5 (Olsen, Cole, Watanabe & Dean (1954)).
(iv) NaOAc pH 4.8 (Morgan (1941)).
(v) NH_4OAc pH 4.8 (Breland (1957)).
(vi) Distilled water (Forsee (1953)).
(vii) 0.002 N H_2SO_4 pH 3.0 (Truog (1930)).
(viii) CO_2 and distilled water (McGeorge (1939)).

Quoting part of their Table 2 (1962) as follows

Extractants	Phosphorus in p.p.m.	
	Gainesville loamy fine sand	Hernando loamy fine sand
0.025N HCl and 0.03N NH_4F	146.4	319.3
0.05N HCl and 0.025N H_2SO_4	123.5	85.4
0.5M $NaHCO_3$	30.7	51.0
NaOAc	12.4	24.9
NH_4OAc	6.3	13.6
Distilled H_2O	3.2	7.1
0.002N H_2SO_4	1.3	2.9
Distilled H_2O and CO_2	1.6	3.5
Average effect of soils	40.7	63.4

It can be seen that the amounts of phosphorus removed from soils varied significantly with extractants. The use of chemical extractants is essentially empirical and the amount of P removed by an extractant does not necessarily indicate that the P is, or would be, available to plants, the best method being that which correlates best with the phosphate responses in the field trials. Very often, one method though applicable to one crop in one area, may however, fail to apply to the same crop in another area having different climatic conditions, soil minerals etc.

The use of ^{32}P as a tracer for the phosphate exchange reactions between solid-liquid phases has been studied by many workers. The advantage in using ^{32}P-phosphate in estimating the amount of exchangeable phosphates is that it does not involve the addition of acids, bases or complexing reagents and is therefore non-destructive in nature. Phosphates in soil that are exchangeable with ^{32}P-phosphate in solution can be adequately regarded as being ultimately available to plants. The degree of availability of the exchangeable phosphates to the plant, will however, depend on the rate at which the phosphates can be released into solution.

Mattingly (1957) commented that (1) so far little progress has been made in analysing the complex curve relating time and the percent of isotopic exchange with the different inorganic fractions of soil phosphorus; and that (2) in most works on the phosphate status of soils, the rate of release of phosphate has seldom been measured and it is possible that more detailed study of the rates of isotopic exchange may help to clarify the conditions under which fixed or precipitated phosphates becomes available for crop growth.

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A technique of Simultaneous Isotope Exchange Kinetics (SIEK) has been developed by the author at the Victoria University of Wellington, New Zealand, whereby the actual activity remaining in solution during the process of isotopic exchange between phosphates of the solid-liquid phases at equilibrium, can be measured and recorded continuously from the moment the ^{32}P-phosphate was introduced to the time exchange reaction reaches completion. The curve of count rate versus time can be analysed mathematically. The activity of the solution as a function of time can be expressed as the sum of a number of logarithmic terms each representing a different type or fraction of inorganic soil phosphate. The rate constants, the amounts of different types of exchangeable phosphates as well as the rates of phosphate release for the soil can therefore be calculated.

Mathematical Theory & Technique

The principle of the method is to first allow chemical equilibrium to be established between a given species in the liquid phase with the species associated with the various adsorption sites on the soild phase and then to introduce a negligible mass of the isotopically labelled species to the liquid phase. The kinetics of the approach to isotopic equilibrium can be followed by the measurement of the radioactivity of the liquid phase. The experimental conditions can be arranged so that the specific activity of the added isotopically labelled species is such that the change in the chemical composition of the liquid is negligible. By suitable analysis of the experimental kinetic data the number of different types of adsorption sites can be determined and each characterized by its rate constant of exchange.

The author does not wish to go into the mathematical details here as this will be discussed at length in a series of papers which are under preparation for publications. The following mathematical relationships are, however, essential for the better understanding of the technique.

$$k_b = \frac{T_o - b}{T_o} \cdot \frac{0.693}{t_{\frac{1}{2}}} \qquad \frac{T_o}{b} = \frac{\emptyset + B}{B}$$

$$k_c = \frac{T_o - b - c}{T_o - b} \cdot \frac{0.693}{t_{\frac{1}{2}}} \qquad \frac{T_o}{c} \cdot \frac{\emptyset}{\emptyset + B} = \frac{\emptyset + B}{C} + 1$$

$$k_d = \frac{T_o - b - c - d}{T_o - b - c} \cdot \frac{0.693}{t_{\frac{1}{2}}} \qquad \frac{T_o}{d} \cdot \frac{\emptyset}{\emptyset + B + C} = \frac{\emptyset + B + C}{D} + 1$$

$$k_e = \frac{T_o - b - c - d - e}{T_o - b - c - d} \cdot \frac{0.693}{t_{\frac{1}{2}}} \qquad \frac{T_o}{e} \cdot \frac{\emptyset}{\emptyset + B + C + D} = \frac{\emptyset + B + C + D}{E} + 1$$

where k_b, k_c, k_d .... are rate constants (minute $^{-1}$.)

T_o is the initial counts/minute of the ^{32}P introduced into the apparatus at zero time.

b, c, d..... are values of intercepts of different extrapolated straight lines.

B, C, D ..... are the amounts of different exchangeable P fractions in terms of mg.P% on the soil.

$\emptyset$ is the amount of P in the equilibrating soil solution in terms of mg.P%

$t_{\frac{1}{2}}$ is the half time of the particular exchange reaction.

The technique involves the use of carrier-free radioactive phosphorus ^{32}P as a tracer in investigating the exchange reactions between solid adsorbed P and the P in solution in a specially designed glass counting apparatus (Graph 1). The solid sample is equilibrated in distilled water until chemical equilibrium is reached between the solid adsorbed P and the solution P. A minute quantity of ^{32}P, an amount so negligible that it would not possibly interfere with the equilibrium, is then added. The ^{32}P exchanges quickly with the adsorbed P on the solid with the result that the activity in solution drops continuously with respect to time and is accordingly recorded on a strip chart recorder. When the ^{32}P activity in solution drops to a steady value indicating that isotopic equilibrium is reached, the data is then plotted on a semi-logarithmic graph paper and analysed. The curve can be resolved into a number of straight lines representing the number of different types or fractions of exchangeable P adsorbed on to the solid surface (Graphs 2, 3&4). Having obtained the values of intercepts of these straight lines, as well as the amount of P in solution, the precise amount of each individual type of exchangeable P can be evaluated. The half-times of the reactions can be determined from the slopes of these straight lines and their specific rate constants can thereafter be calculated. Knowing the rate constants and the amounts of all different types of exchangeable P on the solid surface, the rates of phosphate release of these surface phosphates can be determined.

Counting Equipments

The following counting equipments are required for the work,

(a) High Voltage Supply/Amplifier.

(b) Rate Meter.

(c) Electronic Counter

(d) Strip Chart Recorder.

(e) Electronic Quench Unit

(f) Liquid Geiger Counter

Determination of Equilibration Time for Soils

When soil was added to distilled water, desorption of phosphate into water took place immediately; rapidly at first but slowed down gradually until a state of chemical equilibrium was finally reached.

The time required for the chemical equilibrium to be reached for soil could conveniently be determined as follows,

(1) The counting apparatus (Graph 1) was filled with a known volume of distilled water. The liquid Geiger counter was inserted into compartment B of the apparatus. Glass wool and sand were introduced into compartment C.

(2) One drop of carrier-free ^{32}P was then added into the counting apparatus to give a count rate of say 5,000 - 10,000 counts/minute. The activity was plotted on a Strip Chart Recorder.

(3) At a convenient time, the soil sample (soil: water = 1:100 by weight) was then introduced into compartment C. The ^{32}P in solution would immediately

(i) exchange with the solid phase phosphate

(ii) adsorb onto the solid phase

and the plot of decrease in count rate versus time was therefore shown on the chart. The time required for a steady value to be reached was the equilibration time of the soil. For Egmont top-soil (0-3") whose phosphate status by chemical analysis was shown as follows,

Total P = 256 mg. P%

Organic P = 136 mg. P%

Inorganic P = 120 mg. P%

the steady value was reached on the 11th day.

The soils under investigations were, however, equilibrated for 20 days before kinetic studies.

Determination of "Ø" Value

The amount of phosphate in the equilibrating soil solution (Ø) is determined by the Isobutyl alcohol method (Watanabe & Olsen, 1962).

Experimental Results & Discussions

Before embarking on to complicated soil system, it is advisable to study first simple system such as a phosphated anion-exchange resin. The anion-exchange reactions involving phosphate are known to play an important role in the "phosphate retention" and the "phosphate availability" in soil. Investigations using the SIEK technique have been made by the author on the nature of anion-exchange involving phosphate by the use of an anion-exchange resin, De-Acidite FF (a highly basic resin based upon cross-linked polystyrene containing quaternary ammonium groups) as a model. The advantages offered by the anion-exchange resins are many, namely

(a) It is a simple system, chemically pure and well understood.

(b) It does not fix phosphate, and consequently all phosphates held by the resins are exchangeable.

(c) All the positive sites on the resins are identical to each other. Theoretically speaking, all phosphates held by the resins should be equally available for exchange.

The experimental results obtained by the SIEK technique are shown in Table 1. (Group 2)

Table 1. De-Acidite FF (NaH_2PO_4 treated)
pH 5 25 C

Type of Exchangeable P	$t_{\frac{1}{2}}$ (minute)	k ($x10^{-3} min.^{-1}$)	Amount (Ø)
Very fast exchangeable Phosphate (B)	3.8	109	0.66

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With such a simple system as the De-Acidite FF resins, it is conceivable that all the positive sites on the resins should be identical with each other being $R\text{-}N(CH_3)_3^+$. The SIEK results have in fact shown that this is the case with only one type of exchangeable phosphate adsorbed on it and exchanging with the solution P with a rate constant of

$$k_b = 109 \times 10^{-3} \text{ min.}^{-1}$$

The experimental results for some of the New Zealand natural soils are shown in Table 2. (Graphs 3,4). These soil samples were supplied for studies by the courtesy of the Soil Bureau, Department of Scientific and Industrial Research, Wellington, New Zealand.

Tirau, Egmont and Taupo soils are allophanic in nature. Comparisons of their Total P, Organic P and Inorganic P showed that the Egmont soil would definitely be ranked first, with Tirau second and Taupo last, as far as long term phosphate supplying capacity or phosphate reserve is concerned. These figures, however, do not give indications on true fertility, as far as phosphate availability is concerned.

Estimations of available P by 1 N H_2SO_4, Truog reagent and 1% Citric acid showed that for the H_2SO_4 P, Egmont was the first, with Tirau second and Taupo last. However, for the citric P, Taupo was ranked first, with Egmont second and Tirau the last. Truog P, nevertheless, gave the same results to all indicating same level of fertility for these three soils. It is difficult to decide the order of fertility as far as available P is concerned.

From experimental results obtained by the SIEK technique for the 3 allophanic soils, the following points deserve attention.

(a) The ϕ values were the same for all the three soils and failed to reveal the order of fertility as the Truog P did.

(b) k_b, k_c and k_d were the same for both Tirau and Egmont soil indicating close similarity between the two soils. However, for Egmont, there was the presence of E fraction P (E = 2.02 mg.P% and was 58% of ($\phi + P_e$)) with $k_e = 0.16 \times 10^{-3}\text{min.}^{-1}$. The presence of a similar E fraction P with $k = 0.16 \times 10^{-3}\text{min}^{-1}$ for the Tirau soil is not impossible and its absence could very well be due to

(i) its negligible slope of count rate versus time as compared with that of the other exchangeable P fractions and

(ii) its comparatively smaller amount involved in the exchange with solution P,

and thus made its presence non-detectable. However, its presence or otherwise is of little importance from the fertility point of view and this will be discussed further under "The Rate of Phosphate Release". For Taupo soil, both k_b and k_c were slower than and k_d the same, as the corresponding specific rate constants of Tirau and Egmont. For Taupo, there was, however, the presence of E fraction P (E = 7.03 mg. P% and was 85.5% of ($\phi + P_e$)) with $k_e = 0.06 \times 10^{-3} \text{ min.}^{-1}$.

Table 2. Studies on Natural Soil by SIEK

25° C

Soil	Total P (mg. P%)	Organic P (mg. P%)	Inorganic P (mg. P%)	H_2SO_4 P (mg. P%)	Truog P (mg. P%)	Citric P (mg. P%)	pH of equilibrated solution	[illegible] (min[illegible]
Tirau top soil	143	101	42	33	0.5	10	5.8	B=[illegible] C=[illegible] D=[illegible]
Egmont top soil	256	136	120	98	0.5	12	6	B=[illegible] C=[illegible] D=[illegible] B=[illegible] [illegible]
Taupo top soil	92	67	25	5	0.5	15	5.7	B=[illegible] C=[illegible] D=[illegible] B=[illegible]
Conroy top soil	65	19	46	32	1	13	8.5	B=[illegible] C=[illegible] D=[illegible]
Papakauri top soil	161	103	58	29	0.5	7	4.2	B=[illegible] C=[illegible] D=[illegible] B=[illegible] [illegible]

Tirau (mg.P%)	Egmont (mg. P%)	Remarks
B = 0.54	B = 0.13	0.41 mg. P% in favour of Tirau
C = 1.28	C = 0.27	1.01 mg. P% in favour of Tirau
D = 1.27	D = 0.76	0.51 mg. P% in favour of Tirau
	E = 2.02	2.02 mg. P% in favour of Egmont
P_e = 3.09	P_e = 3.18	

Although P_e as well as ($\phi + P_e$) for Egmont exceeded that of Tirau, 58% of this ($\phi + P_e$) was, however, in the E fraction with $k_e = 0.16 \times 10^{-3}$min.$^{-1}$. Since phosphates in B, C and D fractions were considered to contribute more to the phosphate availability, Tirau was considered to be more fertile than Egmont soil.

P_e = 7.92 mg. P% and ($\phi + P_e$) = 8.22 mg. P% for Taupo versus P_e = 3.18 mg. P% and ($\phi + P_e$) = 3.48 mg. P% for Egmont seemed to place Taupo soil in a more advantageous position. Closer observation showed that of this 8.22 mg. P% ($\phi + P_e$) for the Taupo, 85. 5% was, however, in the E fraction with a very slow $k_e = 0.06 \times 10^{-3}$min.$^{-1}$. The remaining 10.8% was distributed among B, C and D fractions.

Egmont (mg. P%)	Taupo (mg. P%)	
B = 0.13	B = 0.23	0.10 mg.P% in favour of Taupo
C = 0.27	C = 0.09	0.18 mg.P% in favour of Egmont
B+C = 0.40	B+C = 0.32	0.08 mg.P% in favour of Egmont
D = 0.76	D = 0.57	0.19 mg.P% in favour of Egmont

Since k_b and k_c for Taupo were considerably slower than that of Egmont, Taupo was considered to be poorer than Egmont.

The order of fertility in so far as phosphate availability is concerned, for the three allophanic top-soils would therefore be,

1. Tirau
2. Egmont
3. Taupo

in terms of rate of phosphate release (W), the three allophanic top-soil could be expressed as follows,

<u>Tirau</u>

$$W = \{(\underline{33.3} \times 0.54) + (\underline{11.6} \times 1.28) + (\underline{2.5} \times 1.27)\} \times 10^{-3}$$
$$= \{18.0 + 14.9 + 3.2\} \times 10^{-3}$$
$$= 36.1 \times 10^{-3} \text{mg.P\%/minute.}$$

<u>Egmont</u>

$$W = \{(\underline{35.9} \times 0.13)+(\underline{11} \times 0.27)+(\underline{2.8} \times 0.76)+(\underline{0.16} \times 2.02)\} \times 10^{-3}$$
$$= \{4.7 + 3.0 + 2.1 + 0.3\} \times 10^{-3}$$
$$= 10.1 \times 10^{-3} \text{mg.P\%/minute}$$

<u>Taupo</u>

$$W = \{(\underline{21.9} \times 0.23)+(\underline{8.4} \times 0.09)+(\underline{2.1} \times 0.03)+(\underline{0.06} \times 7.03)\} \times 10^{-3}$$
$$= \{5.0 + 0.8 + 1.2 + 0.4\} \times 10^{-3}$$
$$= 7.4 \times 10^{-3} \text{mg.P\%/minute}$$

k ($x10^{-3}$ min.$^{-1}$)	Solution P "Ø" mg. P%	Exchangeable P (P_e) in soil X (mg. P%)	Ø+P_e (mg. P%)	Incr[illegible]
33.3 11.6 2.5	0.3	B = 1.81Ø = 0.54 C = 4.25Ø = 1.28 D = 4.23Ø = 1.27 P_e=10.29Ø = 3.09	3.39	
35.9 11 2.8 0.16	0.3	B = 0.42Ø = 0.13 C = 0.90Ø = 0.27 D = 2.54Ø = 0.76 E = 6.73Ø = 2.02 P_e=10.59Ø = 3.18	3.48	
21.9 8.4 2.1 0.06	0.3	B = 0.78Ø = 0.23 C = 0.31Ø = 0.09 D = 1.91Ø = 0.57 E =23.39Ø = 7.03 P_e=26.39Ø = 7.92	8.22	
48 4.2 0.15	4.2	B = 0.06Ø = 0.25 C = 0.15Ø = 0.63 D = 0.58Ø = 2.44 P_e= 0.79Ø = 3.32	7.52	
30.1 5.7 2.3 0.5	0.11	B = 0.65Ø = 0.07 C = 2.15Ø = 0.24 D = 2.81Ø = 0.31 E = 4.31Ø = 0.47 P_e= 9.92Ø = 1.09	1.20	

P_e= B+C+D+E (total exchangeable P on solid phase)

It should be noticed that the presence of the E fraction P in Egmont soil with $k_e = 0.16 \times 10^{-3}$ $min.^{-1}$ contributed only 0.3×10^{-3} mg.P%/minute to the total W. Assuming the presence of this E fraction P in the Tirau soil, its contribution to the total W would be negligible indeed. The order of fertility in so far as the rate of phosphate release is concerned, for the 3 allophanic top soils would therefore be

1. Tirau soil $W = 36.1 \times 10^{-3}$ mg.P%/minute
2. Egmont soil $W = 10.1 \times 10^{-3}$ mg.P%/minute
3. Taupo $W = 7.4 \times 10^{-3}$ mg.P%/minute

This supports the conclusion reached in (D) above.

For Conroy top-soil (Zonal soil, 13 inches of rain-fall per annum) and Papakauri top-soil (Basaltic soil, 60-65 inches of rainfall per annum), their rates of phosphate release (W) are shown as follows,

Conroy top-soil $W = 15.1 \times 10^{-3}$mg.P%/minute

Papakauri top-soil $W = 4.4 \times 10^{-3}$mgP%/Minute

Conroy top-soil is therefore definitely more fertile than Papakauri top-soil as far as phosphate availabilty is concerned.

The harvesting results obtained by pot trials using White clover (Trifolium repens) conducted separately by Widdowson & Wells (1962) of the Soil Bureau, D.S.I.R. Wellington and by Sherrell (1964) of the Ruakura Agricultural Research Centre, Hamilton, New Zealand, do in fact support the conclusions so reached by the SIEK technique whereas the conventional methods of using chemical extractants have in many cases failed to do so.

Diagrammatic Presentation of Results

The experimental results of the SIEK expressed in physico-chemical terms though self-explanatory to chemists, may, however, prove difficult to understand by farmers. In terms of common language, a schematic presentation as shown in Graph 5. would be helpful. The following points should be noted,

(1) Imagine the different exchangeable phosphate fractions in soil, as tanks of different sizes whose volumes are proportional to the amounts of phosphate in these fractions.

(2) Consider the soil solution as a separate tank (Ø) of unit area at base. The level of P in tank (Ø) then represents the amount of solution phosphates in equilibrium with all the solid phase phosphates. The tank (Ø) is connected to all the P_e tanks as well as to the plant.

(3) These P_e tanks are so placed that the phosphate fraction with the fastest specific rate constant, is the closest to tank (Ø) while the slowest exchangeable phosphate fraction is at the far end.

(4) The phosphate reserve, i.e., the [Inorganic P-(Ø+P_e)] also represented by a tank, is placed at the very far end, with low but unknown specific rate constant.

The organic phosphate and the phosphate precipitate are included only to show the roles played by them and how they fit into the picture. It should be pointed out that the labelling of tanks in terms of 1 minute pool, 1 day pool and 1 week pool is purely arbitrary for clearer illustration.

The diagrammatic presentations for 3 allophanic sub-soils are shown in Graph 6. The following points should be noted,

(1) The scale along the horizontal is logarithmic with tank (Ø) placed at 10 at the extreme left as shown.

(2) The P_e tanks are placed according to their respective specific rate constants. The logarithmic scale is given the unit of $\times 10^{-3} \text{min.}^{-1}$ for the plotting of k.

(3) The distances of these P_e tanks from the tank Ø are represented by 1/k using minutes as units. The faster the specific rate constant, the closer its P_e tank to tank Ø and consequently the shorter the time requirement for the delivery of phosphate into tank Ø.

$$(W_x = k_x X \qquad 1/k_x = X/W_x = \tau_x$$

where τ_x is the average life of P in reservoir x, i.e., the time taken for the reservoir to empty to $\frac{1}{e}$ of its initial value).

(4) Adopting unit length for the base of tank Ø, the level of P expressed in terms of mg. P% in this tank would then represent the amount of Ø.

(5) Since we are considering the system in chemical equilibrium and that the soil is non-fertilized natural soil, the levels of phosphates in P_e tanks should all have the same depth as phosphate in tank Ø. The base of these P_e tanks should be adjusted so that

$$\text{Ø (mg.P\%)} \times \text{base (dimensionless)} = \text{Amount of phosphate in that tank (mg. P\%)}$$

From Graph 6. it can be seen at once that,

(a) Egmont sub-soil is by far the most fertile of the three sub-soils be far as phosphate availability is concerned.

(b) The Egmont sub-soil definitely has the largest phosphate reserve, followed by Taupo and Tirau soils which are comparable with each other.

(c) For Tirau and Taupo soils, the latter as indicated has more available phosphates as can be seen from the depth and size of its tanks (Ø), B, C and D.

Conclusion

The SIEK technique is time consuming and is not recommended for routine determinations. It is however, extremely useful for the determination of phosphate availability of small number of soil profiles from each representative soil type. The SIEK results coupled with the results on total P and Inorganic P determined by the conventional chemical methods should be able to reveal adequately the phosphate status of the soil.

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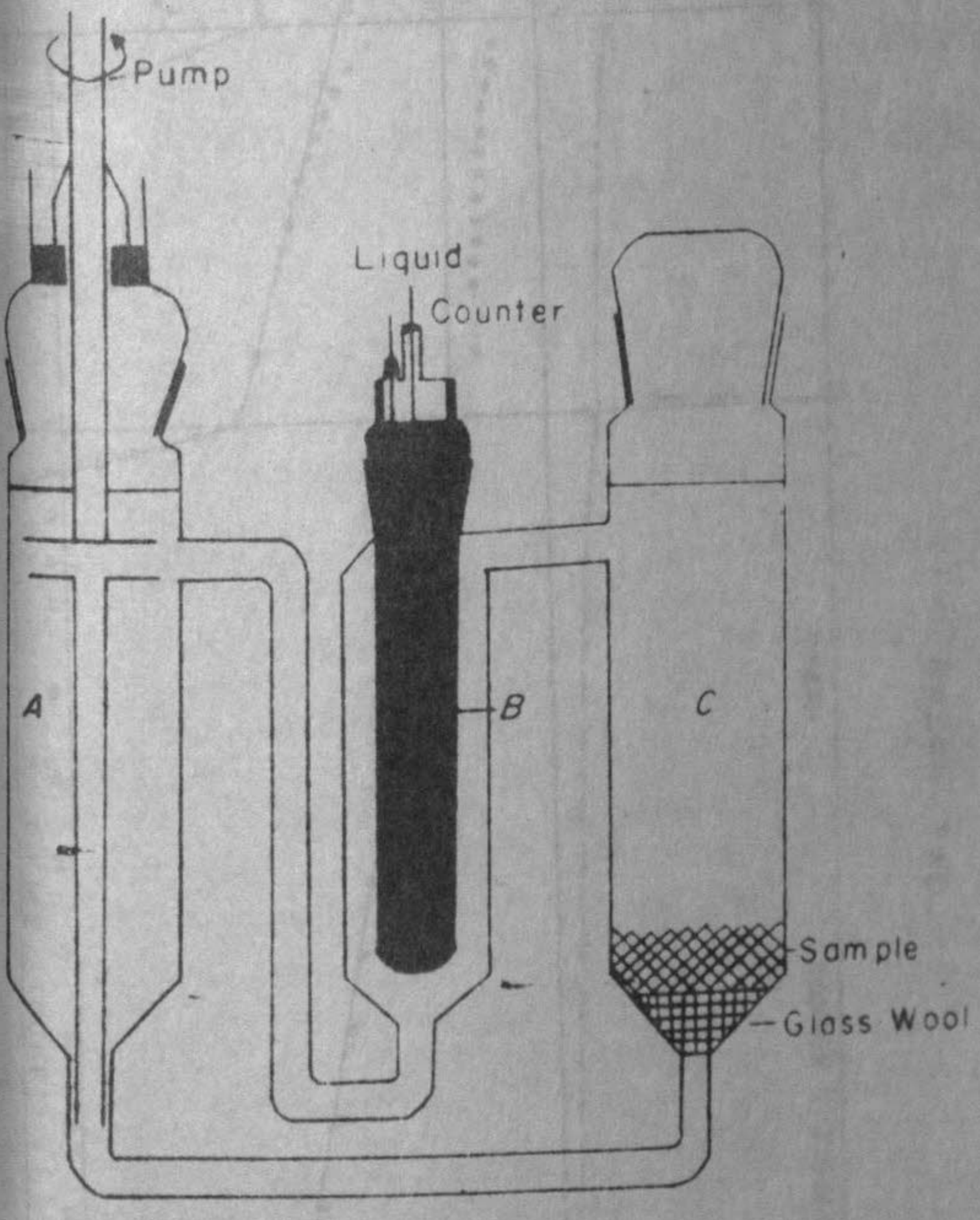
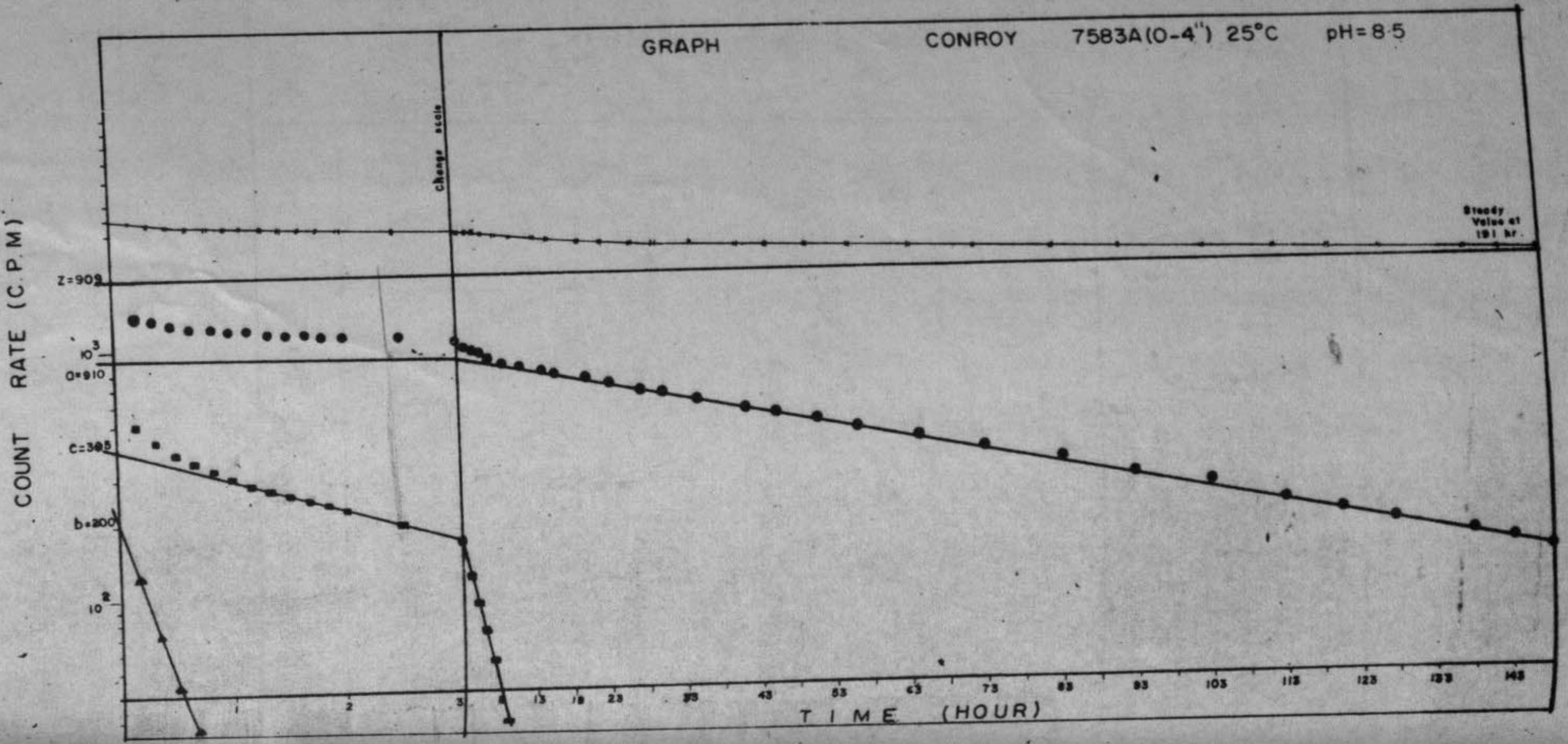
GRAPH ONE

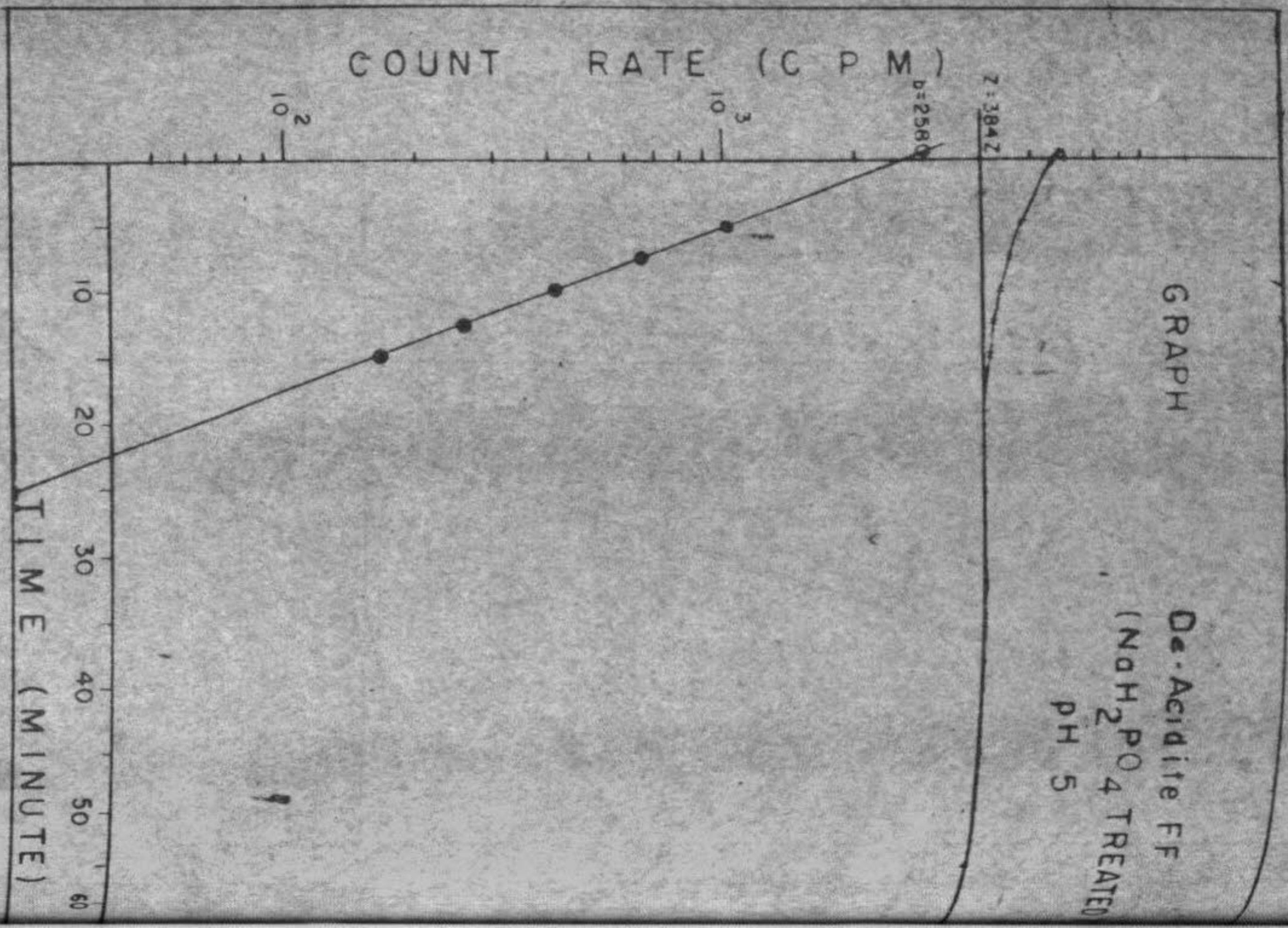


GRAPH TWO



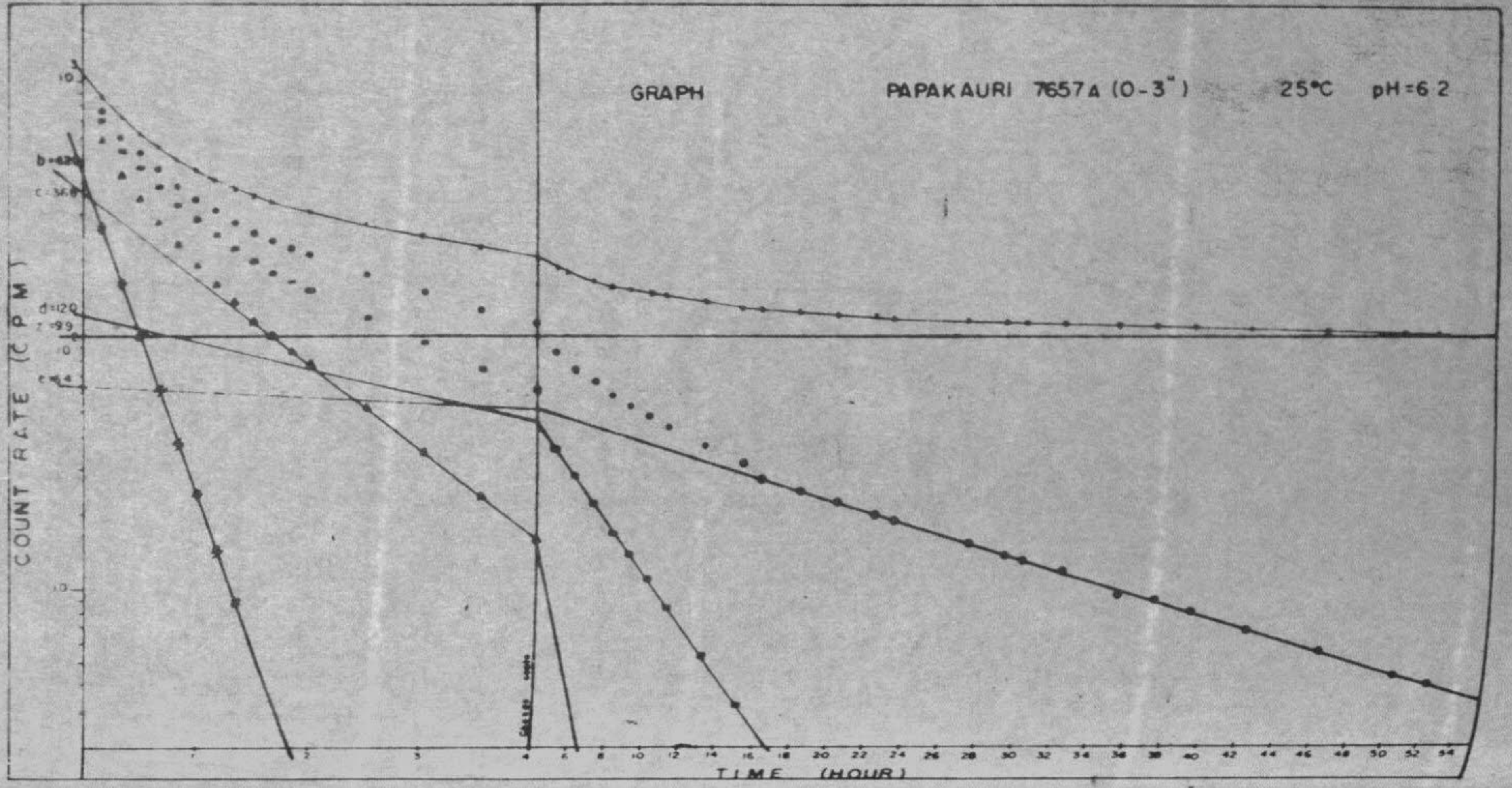
GRAPH
CONROY 7583A(0-4") 25°C pH=8.5
COUNT RATE (C.P.M)
Z=909
10^3
a=910
c=305
b=200
10^2
Change scale
Steady Value at 191 hr.
1
2
3
13
18
23
33
43
53
63
73
83
93
103
113
123
133
143
TIME (HOUR)

GRAPH THREE



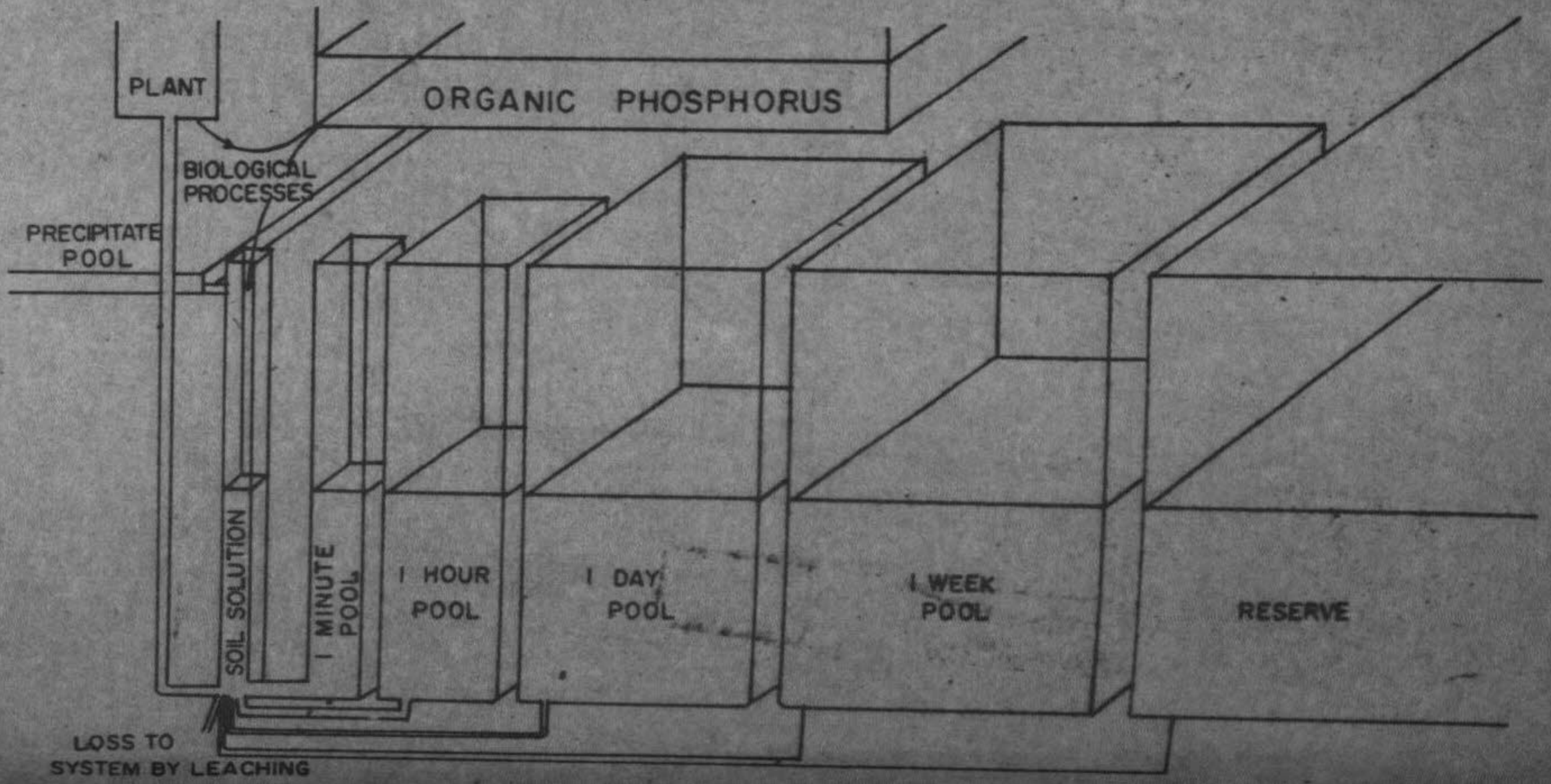
COUNT RATE (C P M)
10 2
10 3
b=2580
Z:3842
TIME (MINUTE)
10
20
30
40
50
60
GRAPH
De-Acidite FF
(NaH2PO4 TREATED
pH 5

GRAPH FOUR

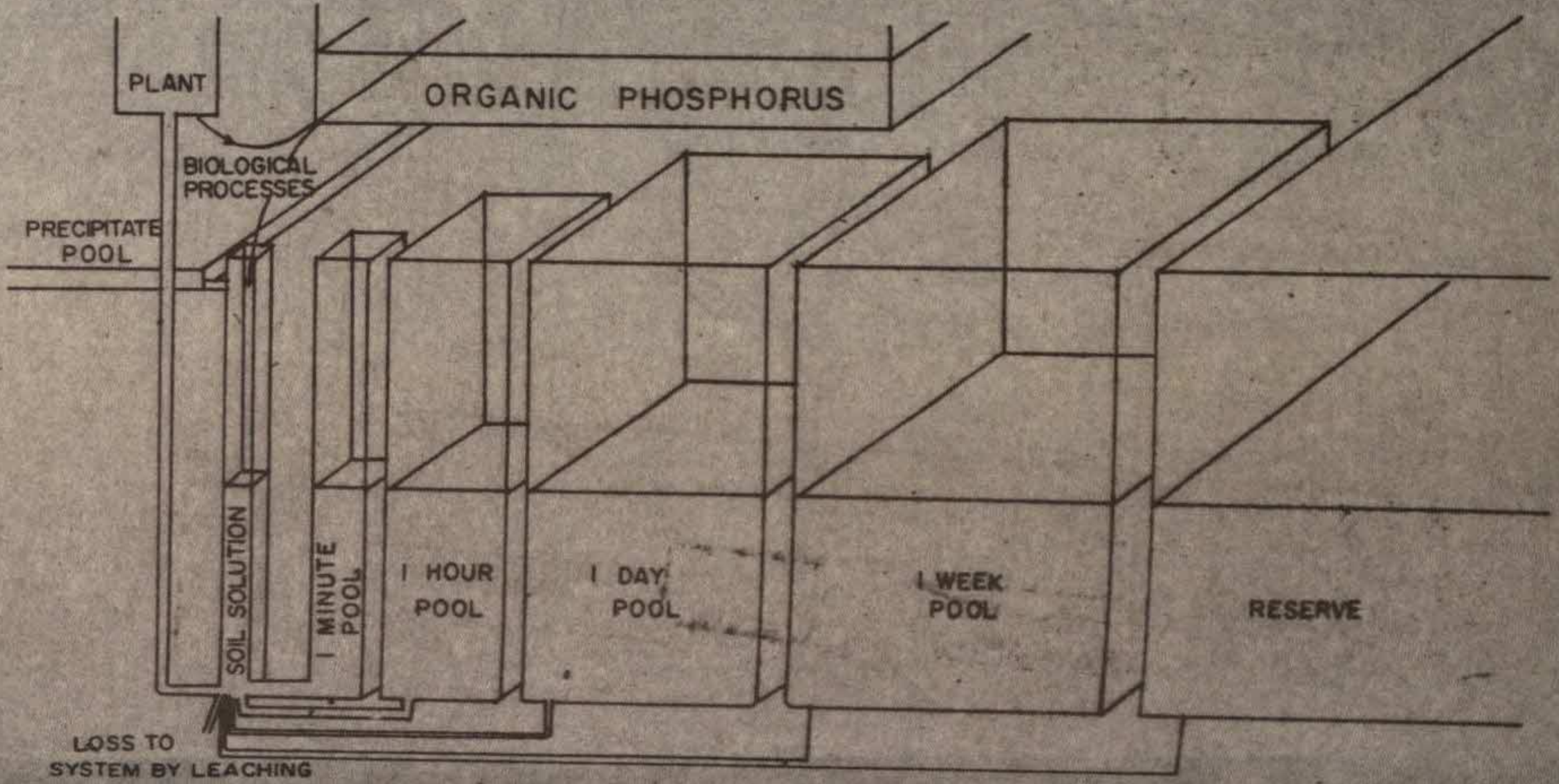


GRAPH
PAPAKAURI 7657A (0-3")
25°C
pH=6.2
COUNT RATE (CPM)
TIME (HOUR)
b=620
c=368
d=120
e=14

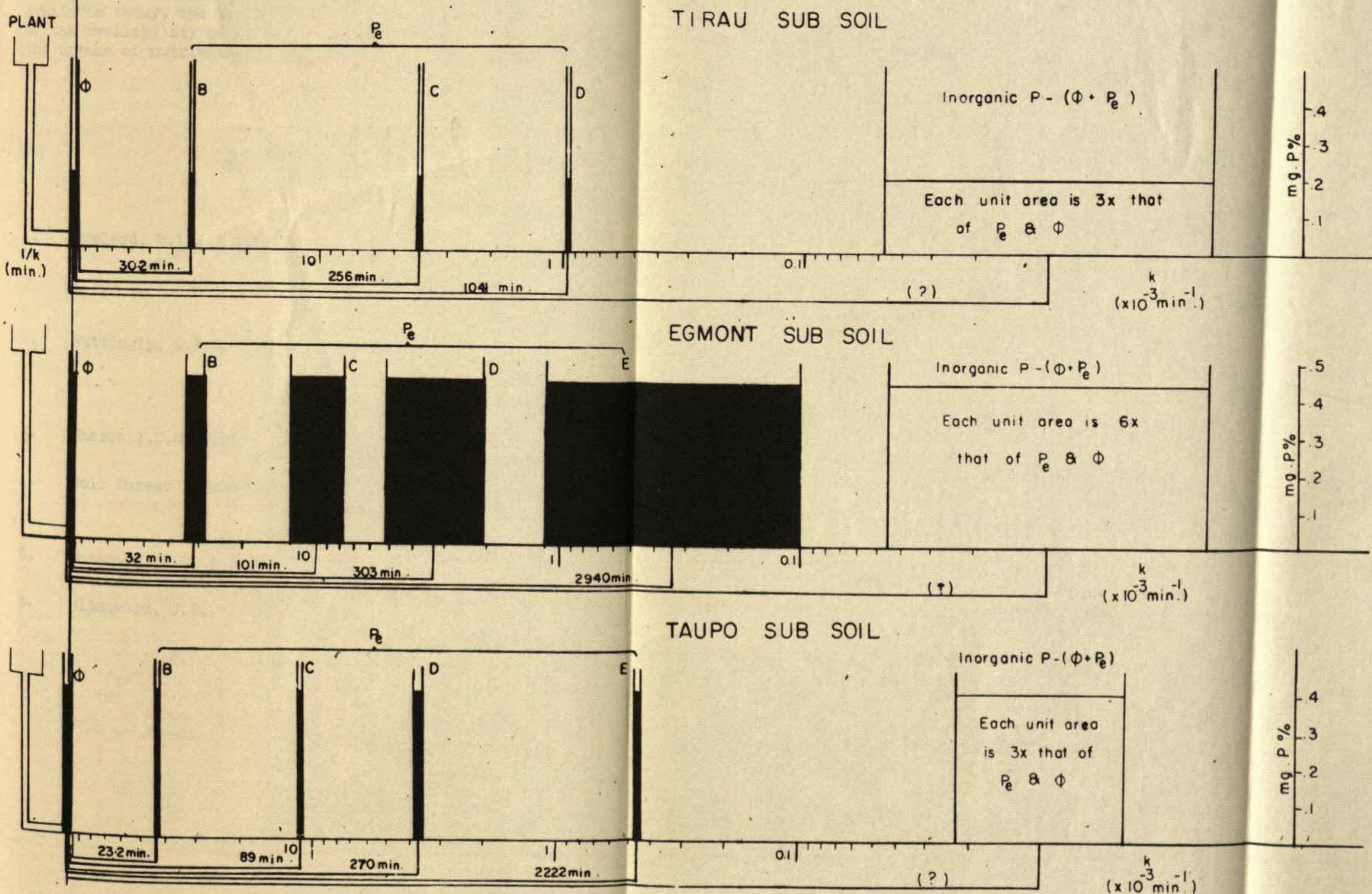
GRAPH FIVE


PLANT
ORGANIC PHOSPHORUS
BIOLOGICAL PROCESSES
PRECIPITATE POOL
SOIL SOLUTION
1 MINUTE POOL
1 HOUR POOL
1 DAY POOL
1 WEEK POOL
RESERVE
LOSS TO SYSTEM BY LEACHING

GRAPH FIVE


PLANT
ORGANIC PHOSPHORUS
BIOLOGICAL PROCESSES
PRECIPITATE POOL
SOIL SOLUTION
I MINUTE POOL
I HOUR POOL
I DAY POOL
I WEEK POOL
RESERVE
LOSS TO SYSTEM BY LEACHING

GRAPH SIX



TIRAU SUB SOIL
PLANT
P_e
Φ
B
C
D
Inorganic P - (Φ + P_e)
Each unit area is 3x that of P_e & Φ
mg. P%
.4
.3
.2
.1
1/k (min.)
30.2 min.
10
256 min.
1
104 min.
0.1
(?)
k ($x10^{-3}min^{-1}$.)
EGMONT SUB SOIL
P_e
Φ
B
C
D
E
Inorganic P -(Φ+P_e)
Each unit area is 6x that of P_e & Φ
mg. P%
.5
.4
.3
.2
.1
32 min.
101 min.
10
303 min.
1
2940 min.
0.1
(?)
k ($x10^{-3}min^{-1}$.)
TAUPO SUB SOIL
P_e
Φ
B
C
D
E
Inorganic P-(Φ+P_e)
Each unit area is 3x that of P_e & Φ
mg. P%
.4
.3
.2
.1
23.2 min.
89 min.
10
270 min.
1
2222 min.
0.1
(?)
k ($x10^{-3}min^{-1}$.)

The theory and technique of SIEK are applicable not only to anions but to cations as well. With the large number of isotopes available today, the technique is extremely valuable for the study of the availability of different plant nutrients in soil and also on the uptake of nutrients by plants.

REFERENCES

1. Breland, H.L., & Sierra, F.A. 1962 Proc. Soil Sci. Soc. Amer. p.348 - 350
2. Mattingly, G.E.G. 1957 Soil & Fertilizers, 20, 59.
3. Sherrell, C.G., 1964 Personal communication.
4. Soil Bureau Information Series No.7 D.S.I.R. Wellington. New Zealand.
5. Watanabe, F.S. & Olsen, S.R., 1962 Soil Science, 93, 183.
6. Widdowson, J.P., & Wells, N., 1964 Personal communication.

DISCUSSION

Bailey: - Could your P^{32} technique be used to determine the state of weathering in soils? It would seem that this technique requirements a very accurate way of determining the state of weathering of a soil.

Shao: - Yes, I think that this technique can be extremely useful in the study of the state of weathering of a soil. If you determine the total P in the parent rock and then the exchangeable P in the soil by the SIEK technique it would be possible to indicate well the state of weathering of the soil.

Kanapathy: - Dr. Shao has certainly a very elegant method but any chemical method must be correlated with plant growth. Was this correlated with field tests or with pot tests?

Shao: - For the three soils tested, good correlations were obtained with pot experiments using clover.

Leamy: - From field experience with the 3 N.Z. soils mentioned by Dr. Shao, I would agree with his statement as to their relative "fertility". I am interested in the possibility of predicting or influencing the type of crop grown according to differing rates of release of P. Would Dr. Shao care to comment?

Shao: - The SIEK technique can be used to predict the suitability of various crops grown on a soil by the determination of the rate of phosphate release of the various exchangeable P fractions. Thus, if a soil has a large value for the rate of release of P (W) and in particular a large value for W_B i.e., the rate of phosphate release for the fastest exchangeable P fraction (B), then this soil would be most suitable for annual crops requiring a large amount of phosphate within a short period of time.

Mohinder Singh: - Is there any specific reason for choosing a soil solution ratio of 1 : 100?

Shao: - This ratio has been chosen for convenience sake only.

Mohinder Singh: - In your measurement of rate constants in your technique the suspension was circulated at a high speed. This would enhance the exchange reaction as compared to normal field conditions where you have diffusion and tortuousity factors.

Shao: - In the SIEK technique the circulation was done at a fast speed in order to avoid diffusion processes, so that only exchange reactions are measured.

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Mohinder Singh: - Are the various fractions, the rate constants of which you measure, discrete fractions or can there be intermingling due to reversion of one form of phosphate to another during measurement.

Shao: - The intermingling is possible. If B and C types intermingle a rate constant intermediate between B and C would then be recorded.

Yeow: - The allophanic soils mentioned have very high phosphate fixing capacity - has the new technique been experimented on soils of lower fixing capacity?

Shao: - In addition to the allophanic soils, rendzinas and basaltic soils were also evaluated.

Hsia: - In your isotopic exchange work have you used activated fertilizers instead of pure P^{32} labelled compounds such as NaH_2PO_4? Would you not think this is worthwhile trying?

Shao: - I have not used irradiated fertilizers but I have used fertilizers labelled with P^{32}. These were dicalcium and tricalcium phosphates and apatite. For dicalcium phosphate there is only one type of phosphate exchange reaction; for tricalcium phosphate and apatite three types. For phosphate retained by Calcium Carbonate there are four types.

Leamy: - Has Dr. Shao done any work on the fate of P applied as fertilizer and on comparison between different fertilizers?

Shao: - I have carried out investigation in which a known amount of dihydrogen phosphate was added to a soil which was kept under two conditions (a) wet throughout and (b) alternate wetting and drying. Results show that of the 100mg. of phosphate added to the soil which was kept under (b) condition, 98% of it remained in the exchangeable fraction. Under condition (a) the exchangeable P fraction was considerably lower. With regard to the comparison of fertilizers, dicalcium phosphate is the best, with tricalcium phosphate second and apatite the last. Monocalcium phosphate was not included in the study because it is entirely soluble in water.

CONTENT OF MAJOR NUTRIENTS IN RUBBER-GROWING SOILS OF MALAYA

By

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INTRODUCTION

The Malayan soils were provisionally classified by OWEN (1951) at series level, but in preparing the 1962 soil map of Malaya PANTON (1964) mapped the soils on the basis of Great Soil Groups of MARBUT, with sub-divisions according to parent materials where possible. The classification at series level is still commonly used for studying the soils under rubber cultivation, though sub-divisions at lower levels of phase and type are also used where needed. Although as many as 90 soil series have so far been described and identified in Malaya (LEAMY AND PANTON, 1965), only about 25 series of soils have been found important for rubber cultivation, the ramaining series of soils being either of localised occurrence or prevalent under other crops, for example, rice, coconut, oil palm etc. These classifications, which are based on pedological considerations with particular emphasis on geology as one of the five soil forming factors, offer valuable information on physical nature and profile characteristics, but provide no understanding of the nutrient contents of the soil. This latter aspect is also considered important from the agronomical point of view, and form the subject of study in this paper.

For offering recommendations on manuring and other cultural practices in rubber plantations, numerous samples collected from different soils have been analysed by the Rubber Research Institute. A summary of the data thus obtained permits a study of the levels of nutrient contents in Malayan soils. The purpose of this paper is to present a preliminary summary of these data and discuss the uniformity or otherwise of the soil nutrient contents within each soil group, and compare it with those of the other soil groups. The relationship between soil and leaf nutrient contents, as shown by simultaneous sampling of both, is also briefly discussed. It is hoped that such a characterisation of the chemical nature of the soils, in addition to the physical nature which is generally taken into consideration for the classification itself, will provide a better understanding of our soil as a medium for growing crops.

EXPERIMENTAL

Sampling

As shown in Table 1, a large number of soil samples to represent the various soil series was collected from rubber estates throughout the country. These samples were collected in two depths, 0 - 6" and 6 - 18", and as a composite sample of ten cores to cover an area of ten to thirty acres of visually uniform soil. The fields of these commercial areas often received regular manuring, but the samples, unless recorded otherwise, were collected in such a way as to avoid these fertilised areas. Further detail and suitability of this sampling method has been discussed before (RUBBER RESEARCH INSTITUTE OF MALAYA, 1962).

Analysis

Notwithstanding the inherent difficulty of interpreting the results obtained by laboratory chemical analysis of soils for availability of nutrients to plants, and many methods appearing in the literature for

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chemical determination of so-called 'available' nutrient in soil, standard procedures of analysis have been followed in the present study. This is because the chemical tests for available nutrients in soil, as used for short term annual crops, is not likely to be applicable for perennial trees like rubber under Malayan conditions. The basic difference seems to lie in the fact that while for satisfactory growth and yield of a quick-growing annual crop a good supply of readily available nutrient is required only over a certain short period, for slow-growing perennial trees with a life cycle of about forty years the presence of such a good supply for a short period is not a suitable criterion. In fact, rubber trees grow satisfactorily in Malaya even though the readily available nutrients in most soils are very low indeed. The more recent concept of Ratio Law by SCHOFIELD (1950) takes both the readily available and reserve forms into account, but the determination of available cations in accordance with this concept is very time-consuming (RAMAMOORTHY AND PALIWAL, 1965). Although investigations on these techniques of measuring chemically the capacity of soils to supply nutrients to rubber trees are now in progress at the Rubber Research Institute of Malaya, the nutrient contents are at present determined both as (a) the readily available form and (b) the reserve or slightly or slowly available form.

The readily available form of phosphorus was determined by extraction with 0.03N ammonium fluoride solution, buffered to pH 1.8 with hydrochloric acid. For potassium and magnesium, the exchangeable contents, as extracted by normal neutral solution of ammonium acetate, were determined. OWEN (1953) studied some biological and chemical methods for determination of available nutrient contents in Malayan rubber-growing soils and concluded that fluoride extraction method was suitable for routine use to assess the relative phosphate status of individual samples, and that for potassium, a determination of the exchangeable content by the standard procedure gives a reliable assessment of the relative potash-supplying capacity of local soils. But this conclusion, at least with respect to potassium, should be reconsidered, as the author himself stated that he had no basis for a proper judgement of the results, as response to treatment with potash was established in only one experiment at that time. Since then, many more cases of both potassium and magnesium responses in the field have been definitely established for rubber in Malaya (BOLTON AND SHORROCKS, 1961; RUBBER RESEARCH INSTITUTE OF MALAYA, 1962, 1963, 1965).

With respect to the reserve or slightly or slowly available form, extraction with concentrated acids was used. Phosphorus was determined by extracting the soil with a 1:1 mixture of conc. sulphuric and perchloric acid. Potassium and magnesium were determined by extracting with constant boiling hydrochloric acid (PIPER, 1950). It must be pointed out that these methods of soil analysis are entirely empirical. While no claim is made on the absolute meaning of these values, for comparison purposes they are useful, particularly in the absence of any other better measure. Besides, at least for potassium, this acid-extractable content in soil appears to be related to the content of the nutrient in rubber leaves (GUHA, 1964).

RESULTS AND DISCUSSIONS

A summary of the results for organic carbon, total nitrogen, acid extractable phosphorus, potassium, and magnesium in the soil samples is graphically presented in Figures 1 to 5 respectively. The available or exchangeable contents for phosphorus, potassium, and magnesium are also included in Figures 3, 4 and 5 respectively. The leaf nutrient contents are shown at the bottom of the figures for the respective elements. For easy presentation and discussion, the concentrations of the elements are classified into a few groups as shown in Table 2. These groups are indicative of the levels that are generally considered very low to very high contents for the Malayan soil and rubber leaf samples. The frequency distribution of the samples in these groups of nutrient contents are shown in the figures. Acid extractable contents are catagorised in six groups,

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whereas for exchangeable contents in soil and for leaf nutrient contents only three groups are used. The following discussion on the frequency distribution of the samples in these groups indicates the characteristic nutrient contents for the different soil series.

Organic carbon

It can be seen from Figure 1 that organic carbon contents in Batu Anam, Rengam, Holyrood, Sungei Buloh and Chemor Series soils are lowest, about 60 - 80% of the samples having 0.50 to 1.00% organic carbon. The remaining samples have contents which fall only in the adjacent groups. The Serdang/Munchong, Malacca and Sitiawan/Sogomana Series soils show only slightly higher organic carbon contents, about 50% of the samples having contents which fall in the next higher group, between 1.01 and 1.50% organic carbon. The remaining two series of soils namely Selangor and Kuantan have highest organic carbon contents. About 80% of the samples from Kuantan Series soil area are in the 1.51 to 2.50% group, and 80% of the samples from Selangor Series soil area have contents which fall in three groups covering 1.51 to $\geq$ 4.00% organic carbon. The organic carbon content is therefore highest (but variable) in the Selangor Series soils.

The carbon contents are lower in the 6 - 18" sub-soil layer than in the 0 - 6" top-soil. A comparison of the figures for the two depths shows that the frequency distribution of the samples generally shifts a step to one lower group for the sub-soil. The distribution pattern however remains very similar in both depths. For the sub-soil layer also, Batu Anam, Rengam, Holyrood, Sungei Buloh and Chemor Series soils show the lowest contents. For both depths, Kuantan and Selangor Series soils show the highest contents, and for these depths the content is variable for Kuantan Series but confined within narrow limited for Selangor Series soils.

Total Nitrogen

The frequency distribution of the samples from 0 - 6" surface soil, given in Figure 2, shows Batu Anam, Rengam, Holyrood, Sungei Buloh and Chemor Series soils to have the lowest total nitrogen contents, about 80% of the samples showing nitrogen content between 0.05 and 0.10% total nitrogen. The remainder of about 20% of the samples have contents between 0.11 and 0.15% nitrogen. For organic carbon also, the distribution was seen to be very similar. Typically, these five series of soils have different physical compositions, Batu Anam Series soils being generally silty clay, the Rengam Series coarse sandy clay, and Holyrood, Sungei Buloh and Chemor Series soils coarse sandy loam to coarse sand. It is interesting to observe that inspite of such differences in their textural composition, their capacity to hold organic matter or humus and total nitrogen seems to be very similar.

For Serdang/Munchong, and Sitiawan/Sogomana Series the total nitrogen content, though higher than in the soils mentioned above, is more variable, only about 50% of the samples falling in any one group, the remaining 50% of the samples being distributed over the adjacent two groups. The content is higher in Serdang/Munchong than in Sitiawan/Sogomana Series, about 50% of the samples being in the 0.11 to 0.15 and 0.05 to 0.10 per cent classes of total nitrogen content respectively. Two soil series, namely Kuantan and Malacca, have nitrogen contents which fall mainly within two groups covering 0.11 to 0.25% nitrogen and thus have higher contents than the other soils studied, except possibly the Selangor Series in which about 30% of the samples have nitrogen contents higher than 0.26%.

The content of total nitrogen, like that of organic carbon, is lower in the sub-soil (6 - 18 in.) than in the top soil. Although the content tends to be somewhat less variable in the sub-soil, the frequency distribution pattern may be considered similar in both layers. A comparison of the figures for both depths for Batu Anam, Serdang and Sitiawan/Sogomana Series shows this clearly.

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The leaf nitrogen contents, also given in Figure 2, correspond in a general way with soil nitrogen contents, in that the leaf samples collected from Selangor and Kuantan Series areas with high soil-nitrogen contents have generally satisfactory leaf-nitrogen contents. As shown in Table 2, a leaf-nitrogen content below 3.0% may be considered low, a content between 3.0 and 3.5% is medium, while values more than 3.5% are considered high (RUBBER RESEARCH INSTITUTE OF MALAYA, 1962). For Selangor Series, about 75% of the leaf samples contain 3.0 to 3.5% nitrogen, while for Kuantan Series about 40% of the samples have between 3.0 and 3.5% and about 60% of the samples have $>$ 3.5% leaf nitrogen. For soils with low nitrogen contents, namely Batu Anam, Sitiawan/Sogomana, Rengam, Holyrood, Sungei Buloh and Chemor Series soils, the leaf-nitrogen content is also low; a considerable number of samples (generally above 30%) have a nitrogen content of less than 3.0% which is indicative of nitrogen deficiency in rubber trees.

The above results show the need for high organic matter status in the rubber-growing soils. The soils with a low organic matter reserve receive regular application of inorganic nitrogen; yet a large number of leaf samples from such areas show nitrogen deficiency. Areas of soils with a high organic matter reserve, on the other hand, though receiving much les and often no nitrogenous fertilisers, show a high nitrogen content in the leaves. Further, a considerable proportion of the rubber-growing areas show nitrogen deficiency in the trees; an increase in the application of nitrogenous fertilisers is therefore desirable in these areas.

Phosphorus

The phosphorus content of the samples is shown in Figure 3. In the 0 - 6" surface soil, acid-extractable phosphorus content is lowest for Batu Anam, Serdang/Munchong, Rengam, Holyrood, Sungei Buloh, and Chemor Series, almost 90% of the samples having content less than 250 p.p.m. Selangor, Malacca and Sitiawan/Sogomana Series soils have a higher content of acid-extractable phosphorus, a considerable proportion of the samples containing between 250 and 500 p.p.m. of phosphorus, although for Malacca and Sitiawan/Sogomana Series the number of samples with 100 to 250 p.p.m. phosphorus is also high. Kuantan Series soils have the highest (but very variable) phosphorus content, about 90% of the samples having a phosphorus content in the wide range of 251 to more than 2000 p.p.m.

The 6 - 18" sub-soil layer contants somewhat lower levels of phosphorus than the surface layer. In the case of Kuantan Series soil, however, the phosphorus levels in both layers are very similar, and the contents are very variable in both layers.

The figures for available phosphorus show that over 70% of the samples from Batu Anam, Serdang/Munchong and Rengam Series soils have less than 11 p.p.m. available phosphorus. Young rubber trees are likely to respond to treatment with phosphate when the available phosphorus in the soil is below this level (OWEN, 1953). Malacca, Holyrood, Sungei Buloh and Chemor Series soils also have appreciable number of samples with less than 11 p.p.m. available phosphorus, but about 50% of the samples have their available phosphorus values between 11 and 30 p.p.m. In the Selangor and Kuantan Series soils, about 90% of the samples have more than 11 p.p.m. available phosphorus; but the content is variable in Selangor Series soils, about 40% of the samples having values of more than 30 p.p.m. compared to only 6% in Kuantan Series soils. Available phosphorus content is highest in Sitiawan/Sogomana Series soils, about 60% of the samples having more than 30 p.p.m. and about 30% of the samples having a content between 11 and 30 p.p.m.

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Phosphorus content in leaves (also included in Figure 3) shows, as would be expected from the soil results, a high phosphorus content in leaves from the Selangor and Kuantan Series soil areas. About 45% of the samples have more than 0.25% phosphorus in the leaves, considered high for rubber leaves; about 45% of the samples have a content between 0.20 and 0.25 per cent - marginal values verging on deficiency. For Batu Anam, Serdang/Munchong, Rengam, Holyrood, Sungei Buloh and Chemor Series soil areas, a considerable number of leaf samples, varying from 20 to 50%, have a leaf phosphorus content less than 0.20%, a level indicative of phosphorus deficiency, although a good proportion of the leaf samples, varying from 40 to 70%, have marginal values of between 0.20 and 0.25 per cent. It is interesting to note that almost all the leaf samples from Malacca Series soil areas show levels of between 0.20 and 0.25% phosphorus; for the Sitiawan/Sogomana Series about 70% of the samples fall within this range and about 25% of the samples have more than 0.25% phosphorus content. The leaf contents for these two soil series appear to be related to the high content of available phosphorus in the soils, although the total content is not very high compared to other soils studied.

Phosphatic fertilsers are widely used in manuring rubber. Heavy application, up to a level of about 5 cwt/acre, is also practiced for manuring cover plants, with the hope that, as the organic matter of the cover plants undergoes decomposition, this applied phosphorus will eventually become available to the rubber trees. The above results of soil and leaf analyses show that although trees on many soils require application of phosphatic fertiliser, this may not be necessary for the Selangor, Kuantan and Sitiawan/Sogomana Series soil areas. Further, the alluvial soils such as the Holyrood, Sungei Buloh, Chemor and Sitiawan/Sogomana Series contain a good proportion of available phosphorus, although their acid-extractable content is not very high. This may be because of their generally low iron content and sandy texture.

Potassium

Potassium contents of the soil and leaf samples are shown in Figure 4. It can be seen that the acid-extractable content in the surface layer is least in the Kuantan Series soil, with 70% of the samples having values between 0.25 and 0.50 m.eq. potassium per 100 gm soil. The remaining 30% of the samples have an even lower potassium content. The soils of Rengam, Holyrood, Sungei Buloh, and Chemor Series may be considered to have a somewhat higher (but very variable) potassium content. The values range from less than 0.25 to 2.00 m.eq. with an almost equal distribution. Batu Anam, Serdang/Munchong, Malacca and Sitiawan/Sogomana Series soils have comparatively higher acid-extractable potassium contents, more than 90% of the samples having contents above 1.00 m.eq. In the case of Serdang/Munchong Series, however, the contents are variable, being almost equally spread over the three groups above 1.00 m.eq. Selangor Series soils show the highest potassium content, about 90% of the samples having more than 2.00 m.eq. potassium.

In the 6 - 18" sub-surface layer, the acid-extractable content of potassium shows a frequency distribution pattern very similar to that in the surface layer discussed above; but unlike carbon, nitrogen and phosphorus content, potassium content tends to be higher in the sub-surface layer than in the surface layer. It appears that a certain amount of potassium has been leached from the surface soil.

The content of exchangeable potassium in the soil samples shows a very different picture from the acid-extractable content. In spite of the very different levels for the acid-extractable contents, the exchangeable content in Batu Anam, Serdang/Munchong, Kuantan, Holyrood, Sungei Buloh, Chemor and Sitiawan/Sogomana Series soils are very similar, 80% to 100% of the samples having content less than 0.15 m.eq. Rengam and

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Malacca Series soils may be considered to have a higher exchangeable potassium content, as more than 40% of the samples contain exchangeable potassium between 0.15 and 0.30 m.eq., although about 50% of the samples have less than 0.15 m.eq. Exchangeable potassium is highest in Selangor Series soils, about 40% of the samples having values more than 0.30 m.eq. and about 50% having values between 0.15 and 0.30 m.eq.

Potassium content in leaf samples is least for Kuantan Series soil area, about 90% of the samples having less than 1.00% potassium, a level below which trees are considered to be deficient in potassium (RUBBER RESEARCH INSTITUTE OF MALAYA, 1962). In Rengam, Holyrood, Sungei Buloh and Chemor Series soil areas also, about 50% of the leaf samples show less than 1.00% potassium and more than 40% of the samples have potassium in the range 1.0 to 1.4% which is considered marginal. For Batu Anam, Serdang/Munchong, Malacca, Sitiawan/Sogomana Series soil areas, the leaf nutrient content is higher, 20 to 40% of the samples having more than 1.4% potassium and 40 to 60% of the samples falling within the range 1.0 to 1.4% potassium. It can be observed that the exchangeable-potassium contents in all these soils were not materially different, although acid-extractable content was higher for Batu Anam, Serdang/Munchong, Malacca and Sitiawan/Sogomana Series. The potassium content in rubber leaf therefore appears to be related to the acid-extractable content in soil, particularly when the exchangeable contents are very low. For Selangor Series where both acid-extractable and exchangeable-potassium contents in soil are high, leaf potassium also shows very high content, 60% of the leaf samples have more than 1.40% potassium and about 30% of the samples have potassium contents between 1.0 to 1.4%.

The results of soil and leaf analyses indicate that a considerable increase in potassium manuring may be needed for Kuantan Series soil areas; for the Rengam, Holyrood, Sungei Buloh and Chemor Series soil areas also, potassium levels in soils and leaves cannot be considered generally satisfactory. For other soils studied, particularly for Selangor Series soils, the potassium status of soils and leaves is satisfactory.

Magnesium

The magnesium content of the soil and leaf samples is shown in Figure 5. For the 0 - 6" surface layer, Rengam, Holyrood, Sungei Buloh and Chemor Series soils have the lowest content of acid extractable magnesium. In fact, coarse sandy clay Rengam Series soil, with about 80% of the samples having contents less than 1.00 m.eq. magnesium per 100 gm soil, has an even lower magnesium content than the coarse sandy Holyrood, Sungei Buloh and Chemor Series soils. Batu Anam and Sitiawan/Sogomana Series soils have the next highest contents, about 80% of the samples having acid-extractable magnesium within the range 1.01 to 3.00 m.eq. per cent. The contents in Serdang/Munchong, Kuantan and Malacca Series soils are higher, but variable. In Serdang/Munchong and Malacca Series soils, the samples are almost equally distributed in the three groups covering from 1.01 to 10.00 m.eq., while in Kuantan Series the number of samples in the 1.01 to 3.00 m.eq. range reaches a level as high as 50%. The high magnesium and low potassium contents of Kuantan Series soil appear to be related to the nature of the basaltic parent material of the soil which is known to have a high magnesium but a low potassium content. Of the soils studied, Selangor Series soils have the consistently highest magnesium content, about 80% of the samples having more than 10 m.eq. acid-extractable magnesium.

The acid-extractable magnesium contents of the different soils appear to have a very similar frequency distribution for both the 0 - 6" surface layer and the 6 - 18" sub-surface layer, although the actual amount tends to be somewhat higher in the sub-surface layer, as was observed in the case of potassium also.

For exchangeable-magnesium content, Batu Anam, Serdang/Munchong, Rengam and Sitiawan/Sogomana Series soils show the lowest levels, about 60 to 80% of the samples having less than 0.15 m.eq. magnesium. Malacca,

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Holyrood, Sungei Buloh, Chemor Series soils have the next highest levels of exchangeable magnesium contents, about 60% of the samples having contents between 0.15 and 0.30 m.eq. In the case of Kuantan Series soil, however, the entire number of samples analysed falls within the same range 0.15 to 0.30 m.eq. Selangor Series soils have the highest levels of exchangeable magnesium content, about 75% of the samples having contents above 0.30 m.eq.

The leaf samples from Holyrood, Sungei Buloh and Chemor Series soil areas have the lowest levels of magnesium content. About 50% of the samples, having less than 0.20% magnesium, are considered deficient in magnesium. For Serdang/Munchong, Rengam and Malacca Series, the leaf samples show higher levels. About 40% of the samples have contents between 0.20 and 0.25% and about 50% of the samples have above 0.25% magnesium, a satisfactory level in rubber leaves. The next highest level for magnesium content in leaves is found in Batu Anam and Sitiawan/Sogomana Series soil areas; about 70% of the leaf samples have contents higher than 0.25% magnesium. Leaf magnesium content is highest for Selangor and Kuantan Series soils where 86 and 100% of the samples respectively have contents higher than 0.25% magnesium.

The results show that, while for Selangor and Kuantan Series the magnesium content in soil and leaf samples may be considered generally satisfactory, for Holyrood, Sungei Buloh and Chemor Series this is generally below the satisfactory levels. For other soils studied, the results are marginal and variable. Moreover, for these soils the relationship between soil and leaf magnesium contents is not clear, probably because of the potassium/Magnesium interaction in plant uptake.

SUMMARY

Contents of major nutrients in soil and leaf samples from about 600 sites representing the more important rubber growing soils of Malaya are presented. Comparison of the soil results within a soil group or between soil groups permitted characterisation and grading of the soils with respect to each nutrient.

With some limitations, a close relationship between soil and leaf nutrient contents has been observed. The results for the different soil groups are briefly discussed in relation to the fertiliser requirement in rubber cultivation.

ACKNOWLEDGEMENTS

The work of the staff of the Soils Division who collected the soil and leaf samples and carried out the analytical work, is gratefully acknowledged.

REFERENCES

BOLTON, J. and SHORROCKS, V.M. (1961) The effect of magnesium limestone and other fertilisers on a mature planting of Hevea brasiliensis. J. Rubb. Res. Inst. Malaya 17, 31.

GUHA, M.M. (1964) The effect of soil type and nutrient contents on the fertiliser requirements of Hevea brasiliensis. Conference of Malaysian soil surveyors, Tauran Sabah, 1964.

GUHA, M.M. (1965) Soils and manuring of rubber in Malaya. The Planter, Kuala Lumpur, XLI, No.5, 1.

.../178

LEAMY, M.L. and PANTON, W.P. (1965) Soil Survey Manual. Soil Science Division, Department of Agriculture, States of Malaya, Kuala Lumpur.

OWEN, G. (1951) A provisional classification of Malayan soils. J. Soil Sci. 11, No.1, 20.

OWEN, G. (1953) Determination of available nutrients in Malayan soils. J. Rubb. Res. Inst.Malaya, 14, 109.

OWEN, G. (1953) Studies on the phosphate problem in Malayan soils. J. Rubb. Res.Inst. Malaya, 14, 121.

PANTON, W.P. (1964) The 1962 soil map of Malaya. J. Trop. Geogr. 18, 118.

PIPER, C. S. (1950) Soil and plant analysis. University of Adelaide.

RAMAMOORTHY, B and PALIWAL, K.V. (1965) Potassium absorption ratio of some soils in relation to their potassium availability to paddy. Soil Sci. 99, No.4.

RUBBER RESEARCH INSTITUTE OF MALAYA (1962) Rep. Rubb. Res. Inst. Malaya 1962, 19

RUBBER RESEARCH INSTITUTE OF MALAYA (1963) Rep. Rubb. Res. Inst. Malaya 1963, 16.

RUBBER RESEARCH INSTITUTE OF MALAYA (1965) Planters' Bull. Rubb. Res. Inst. Malaya, 77, 36.

SCHOFIELD, R.K. (1950) Quoted by E.W. Russel in Soil conditions and plant growth, 8th ed. p.111. Longmanns, Green, London.

DISCUSSION

Kanapathy:

- It appears that there is good correlation between available P and leaf P. What method was used to determine available P?

Guha:

- The available P is determined by the acid fluoride method.

Andriesse:

- How do you correlate the nutrient status of soil which has been fertilised, with soil series?

Guha:

- The factors influencing the soil and leaf content in estates are numerous and are inherent in the present results, but the effect due to fertilizers, as shown in previous studies, are of much lower order to affect the general picture presented here.

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Pushparajah: - To elaborate on Guha's statement; it has been seen that no doubt fertilizer applications have raised the leaf nutrient contents; but the order of differences that exists between two soils say Rengam and Serdang for K is not altered. Up to now the form of fertilizers applied have been of similar composition for inland loams and another mixture for sandy soils. These have now been found to be somewhat inadequate. So, the inherent differences found on control plots (unfertilised plots in experiments) are often reflected under present day estate practice. It must be said that the order of differences are detectable but the absolute values may be somewhat higher.

Leamy: - I question the validity of the statement on p.1 that "These classifications .... provide no understanding of the nutrient contents of the soils."

Guha: - I would agree that "some understanding" would have been more appropriate.

Smallwood: - Have you taken into account past fertilizer treatments and their influence over a long period of years e.g. their residual effect, especially in soils planted with rubber which has had various treatments of fertilizers.

Guha: - From our previous studies, the effect of fertilizer application on the nutrient status of a soil over a 5-year period was found to be little and even if we took such an effect into consideration, the picture presented would still prevail.

Watson: - I do not think it is valid to use soil not fertilized for matching against data of leaf analysis from areas which were fertilized.

Wong: - Has any attempt been made to correlate the variability of phosphorus and carbon in the Kuantan Series to the physical attributes, such as slope, of the soil or to some other inherent properties such as its pedological age.

Guha: - No! but we intend to do this when we have acquired sufficient data.

Law: - (a) Am I correct to assume that the depth of sampling of 0-6" and 6-18" has been determined by the root distribution of the rubber tree?

(b) Soil structure, consistence do affect the distribution of roots and I would like to know if this has been taken into account.

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Yeow: - The R.R.I. found that 75% of rubber roots are in the top 3 feet of soil and the sampling method was determined by practical considerations.

Chairman: - The authors of this paper have determined the nutrients status of some soils now under rubber in estates. Very useful information have been obtained but from the foregoing discussions, it does appear that before valid distinctions between soil series can be made, the factor of management including fertilization,cover cropping etc. and method of soil sampling have to be defined more exactly.

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TABLE 1

RUBBER GROWING SOILS OF MALAYA WITH NUMBER OF SOIL SAMPLES STUDIED

Great Soil Group	Approximate Area under Rubber* (acres)	Typical Soil Series	No. of Sites sampled
MODERATELY OR POORLY DRAINED LOW HUMIC GLEY SOILS ON COASTAL PLAINS	910,000	Selangor	125
RED AND YELLOW LATOSOLS DERIVED FROM SEDIMENTARY PARENT MATERIALS	925,000	Batu Anam Serdang/Munchong	75 130
RED AND YELLOW LATOSOLS FROM ACID IGNEOUS PARENT MATERIALS	855,000	Rengam	117
REDDISH BROWN LATOSOLS DERIVED FROM INTERMEDIATE AND BASIC IGNEOUS PARENT MATERIALS	23,000	Kuantan	31
LATERITIC SOILS DERIVED FROM SEDIMENTARY PARENT MATERIALS	928,000	Malacca	33
LATOSOLS DEVELOPED ON INLAND TERRACE ALLUVIUM	217,000	Sungei Buloh, Chemor, Holyrood Sitiawan/Sogomans	33 56
Total	3,858.000		600

* Guha (1965)

FIGURE 1. CARBON CONTENT

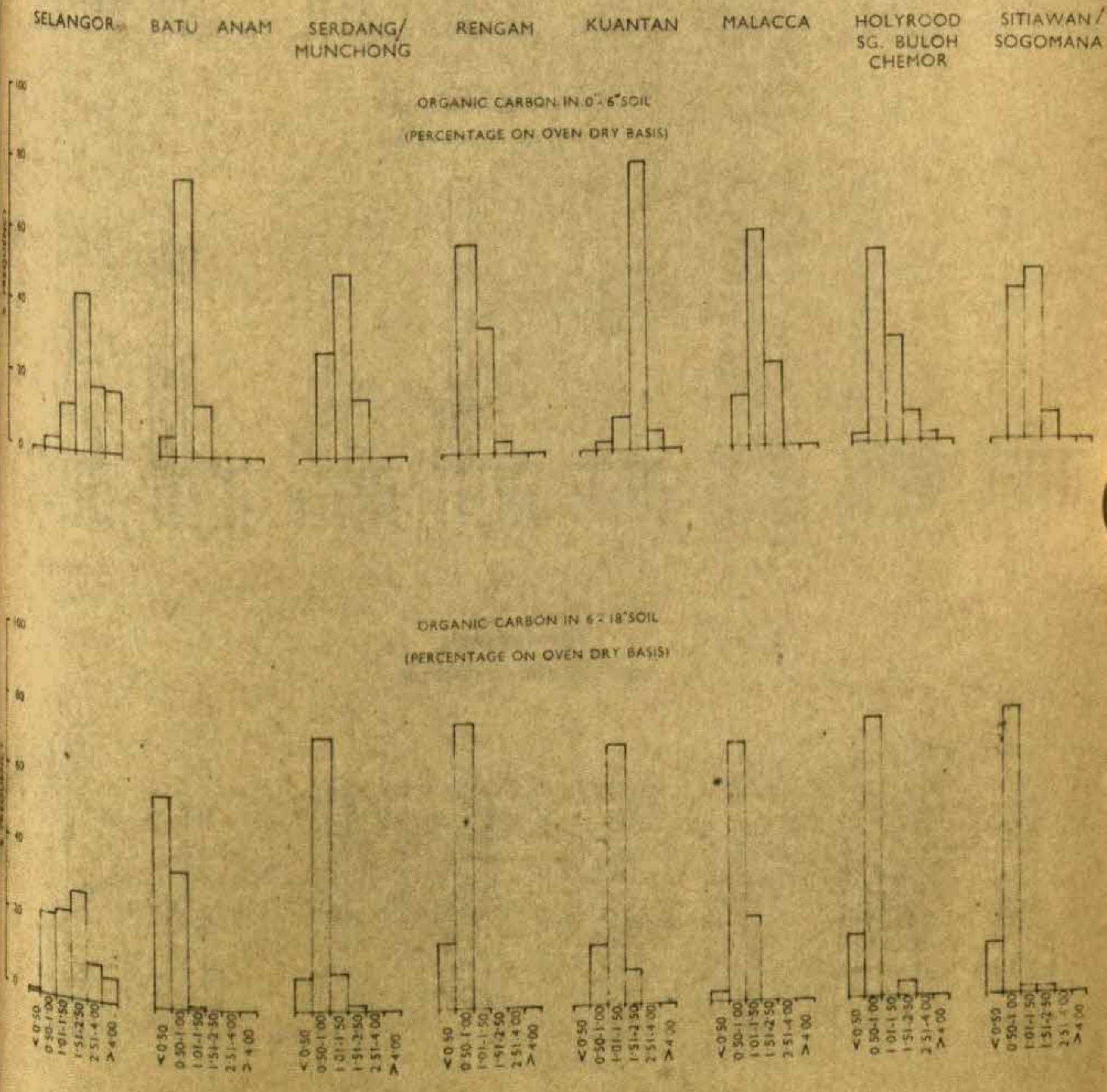

FIGURE 2. NITROGEN CONTENT

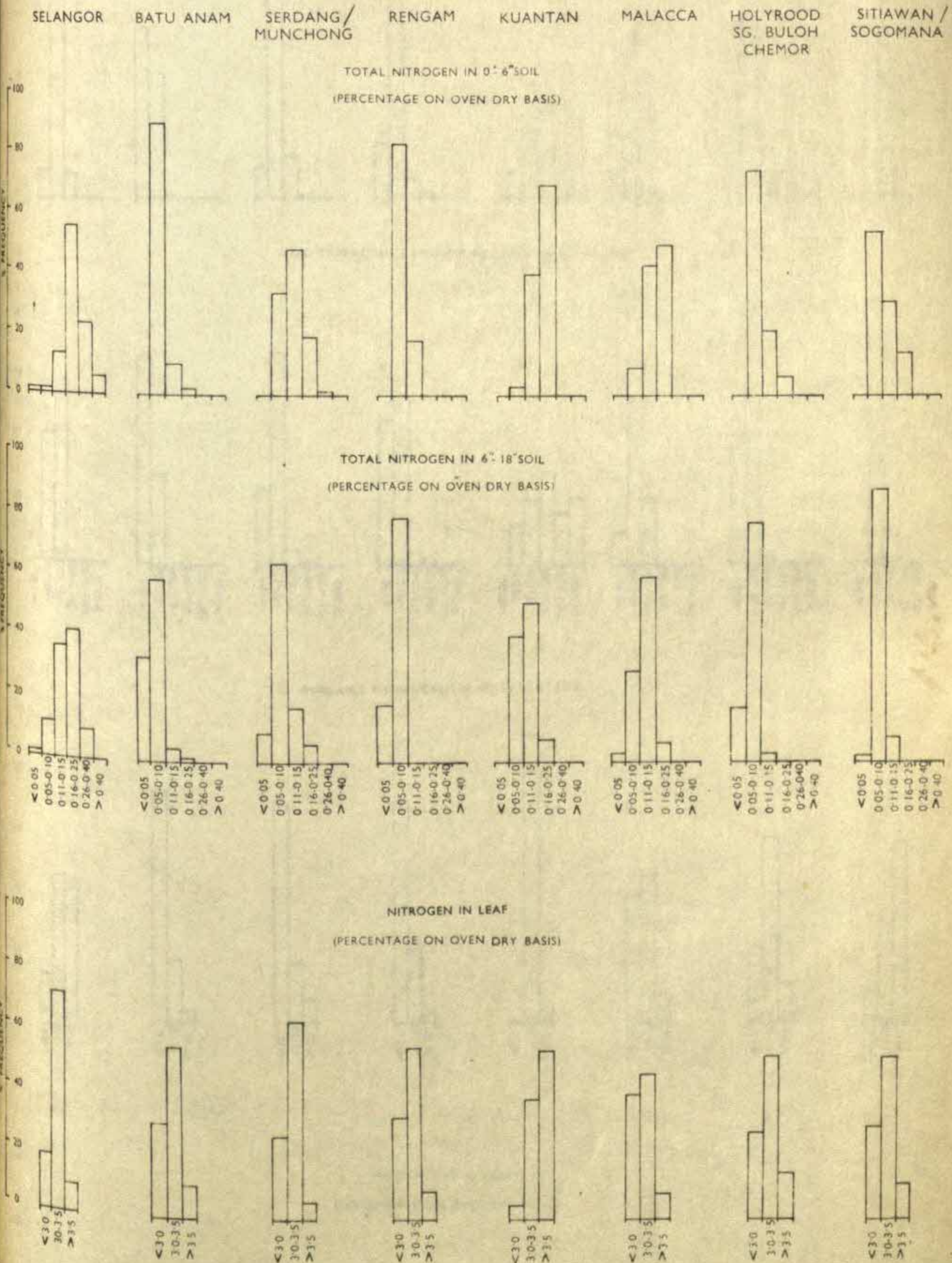

FIGURE 3. PHOSPHORUS CONTENT

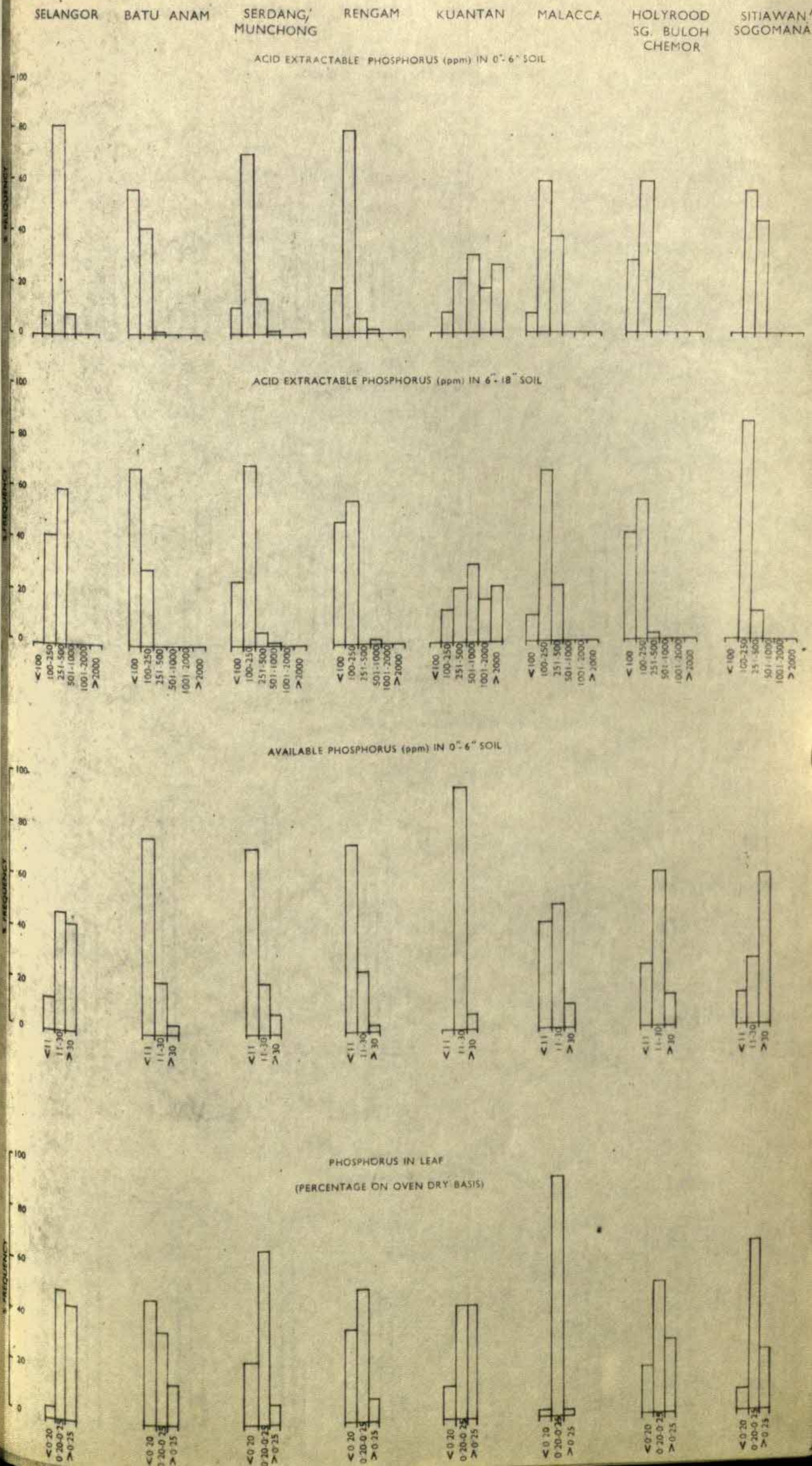

FIGURE 4. POTASSIUM CONTENT

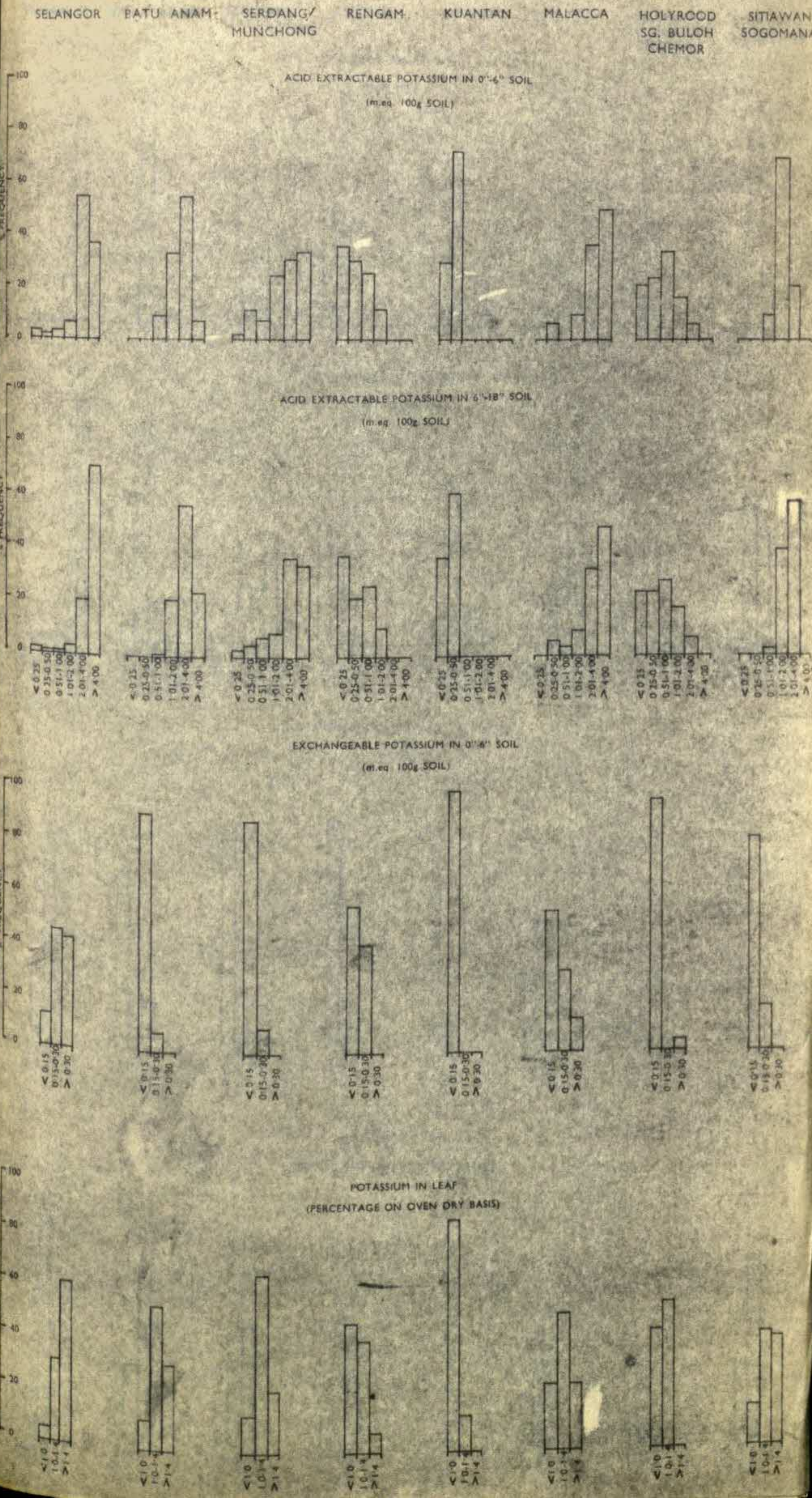

FIGURE 5. MAGNESIUM CONTENT

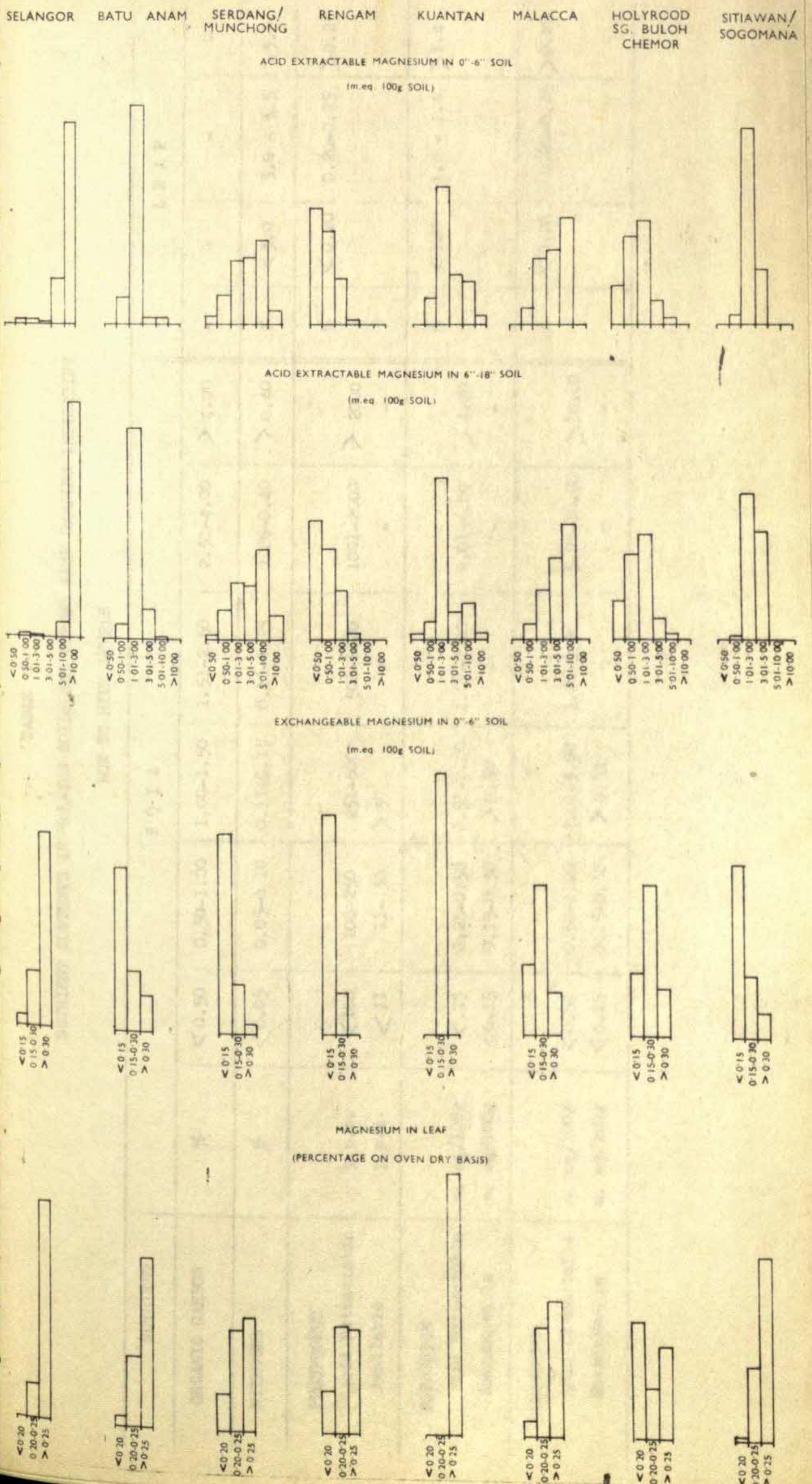

TABLE 2

NUTRIENT CONTENTS IN MALAYAN SOILS AND RUBBER LEAF SAMPLES INDICATING

LOW TO HIGH LEVELS

NUTRIENT	SOIL							LEAF			
ORGANIC CARBON	%	<0.50	0.50-1.00	1.00-1.50	1.51-2.50	2.51-4.00	> 4.00	-	-	-	-
NITROGEN	%	<0.05	0.05-0.10	0.11-0.15	0.16-0.25	0.26-0.40	> 0.40	%	<3.0	3.0 - 3.5	>3.5
PHOSPHORUS								%	< 0.20	0.20-0.25	>0.25
Acid Extractable	p.p.m.	<100	100-250	251-500	501-1000	1001-2000	> 2000				
Available	p.p.m.	<11	11- 30	> 30	-	-	-				
POTASSIUM								%	<1.0	1.0 - 1.4	>1.4
Acid Extractable	m. eq/100g	<.25	0.25-0.50	0.51-1.00	1.01-2.00	2.01-4.00	> 4.00				
Exchangeable	m. eq/100g	<0.15	0.15-0.30	> 0.30	-	-	-				
MAGNESIUM								%	<0.20	0.20-0.25	>0.25
Acid Extractable	m. eq/100g	<0.50	0.50-1.00	1.01-3.00	3.01-5.00	5.01-10.00	>10.00				
Exchangeable	m. eq/100g	<0.15	0.15-0.30	> 0.30	-	-	-				

CHEMICAL & AGRONOMICAL STUDIES OF A COMMON UPLAND SOIL IN SARAWAK

by

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(This work forms part of a paper which is being considered for publication elsewhere and is, therefore, not for publication.)

In September 1964 a field experiment was laid down at the Semongok Agricultural Research Station about 13 miles from Kuching, to study the effect of three inorganic fertilisers, on their own and in combination, on the chemical properties of a common residual soil and on the resultant growth of rice, the subsequent maize growth and natural regrowth. The soil chosen, a red-yellow podsolic, was typical of many residual hill soils in Sarawak. Table I gives the chemical and physical composition of the soil.

The three fertilisers used were mono-calcium phosphate, potassium chloride and ammonium sulphate. The experimental layout was of factorial design with the three fertiliser each applied at three levels; namely 0, 36 lbs P., 72 lbs P/acre; 0, 15 lbs K, 30 lbs K/acre and 0, 40 lbs N, 80 lbs N/acre. The main results are summarised in Figures 1-4. (one star indicates significance at the 5% level, two stars, 1% and three stars 0.1% level).

The reactions of mono-calcium phosphate were mainly controlled by iron and aluminium. The latter dominated the exchange complex and acidity reactions while both iron and aluminium played major roles in phosphate transformations. Potassium interacted with phosphate to increase the amount of aluminium and iron bound phosphates and this was reflected by more vigorous second and third crop growth on those plots which had received both potassium chloride and mono-calcium phosphate. This is of agricultural interest because it means that the residual effect of phosphate can be increased in this soil, by the simultaneous addition of potassium chloride.

All three fertilisers had residual effects on the growth of maize after eight months and natural regrowth after fourteen months. The order of effect being mono-calcium phosphate > potassium chloride > ammonium sulphate. The fact that the latter two fertilisers had residual effects is interesting because this soil was highly leached and the dominant clay mineral is of the kaolinitic type.

DISCUSSION

Mohinder Singh: - Could you give a brief explanation about the measured increase of C.E.C. of the soil by application of KCl?
What is the interval between sampling?

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Bailey: - The increase in C.E.C. can be due to

(i) an increase in organic matter as a result of application of K.

(ii) the increase in negative charges on the clay surfaces due to reaction of soluble P with Al and Fe in the clay.

The soil samples were taken after one crop of hill padi (about a nine month interval)

Shao: - Your Fig.4 You have mentioned the interaction between P and K. Are you sure that divalent Ca ions have no effect at all?

Bailey: - It is likely that Ca would come into reaction in the experiment.

Kanapathy: - In your experiments was the straw removed from the field as on decomposition of the straw C.E.C. would be increased?

Bailey: - The straw was not removed from the field. The effect you mention is probably one of the causes of increasing the C.E.C.

Birch: - In your result exchangeable Al was decreased by increasing levels of K. Is this due to the replacing of Al by K and the subsequent fixation of the Al by P.

Bailey: - Yes, I would subscribe to your explanation that the displaced Al could react with P and be precipitated out as aluminium phosphate which could also incorporate some of the K.

Table I. Chemical and Physical Composition of Control Plot Soil

Det. / Depth inches	%* SiO_2	% Fe_2O_3	% Al_2O_3	% TiO_2	% CaO	% MgO	% Na_2O	% K_2O	% MnO	% P_2O_5	of loss between 250°C - 350°C.	% loss between 350° - 1000°C.	Total Chemical composition	Mechanical analysis				Total mechanical composition includes % loss at 250° - 350°C
														% Silt	% Clay	% Sand	Total	
0-6	71.64	4.69	13.05	0.96	0.21	0.29	0.19	0.35	<.01	0.05	4.88	7.36	100.73	37.77	46.51	11.48	95.76	100.64
6-12	68.75	5.72	15.63	1.00	0.27	0.31	0.16	0.39	<.01	0.04	2.28	6.05	100.61	38.50	51.23	10.48	100.24	102.49
12-18	66.48	6.62	17.22	0.96	0.23	0.31	0.19	0.55	<.01	0.05	2.24	5.89	100.75	33.77	56.90	8.47	99.14	101.38
18-24	61.55	7.50	20.10	1.00	0.20	0.32	0.19	0.60	<.01	0.05	2.69	6.31	100.51	32.12	59.87	7.74	99.74	102.43

* All determinations are reported on an oven dry basis.

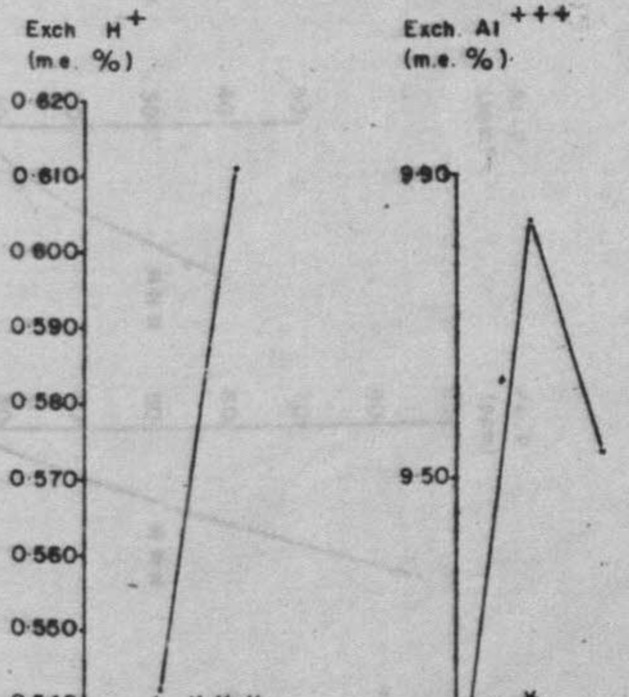

Figure 1: Effect of Ammonium Sulphate

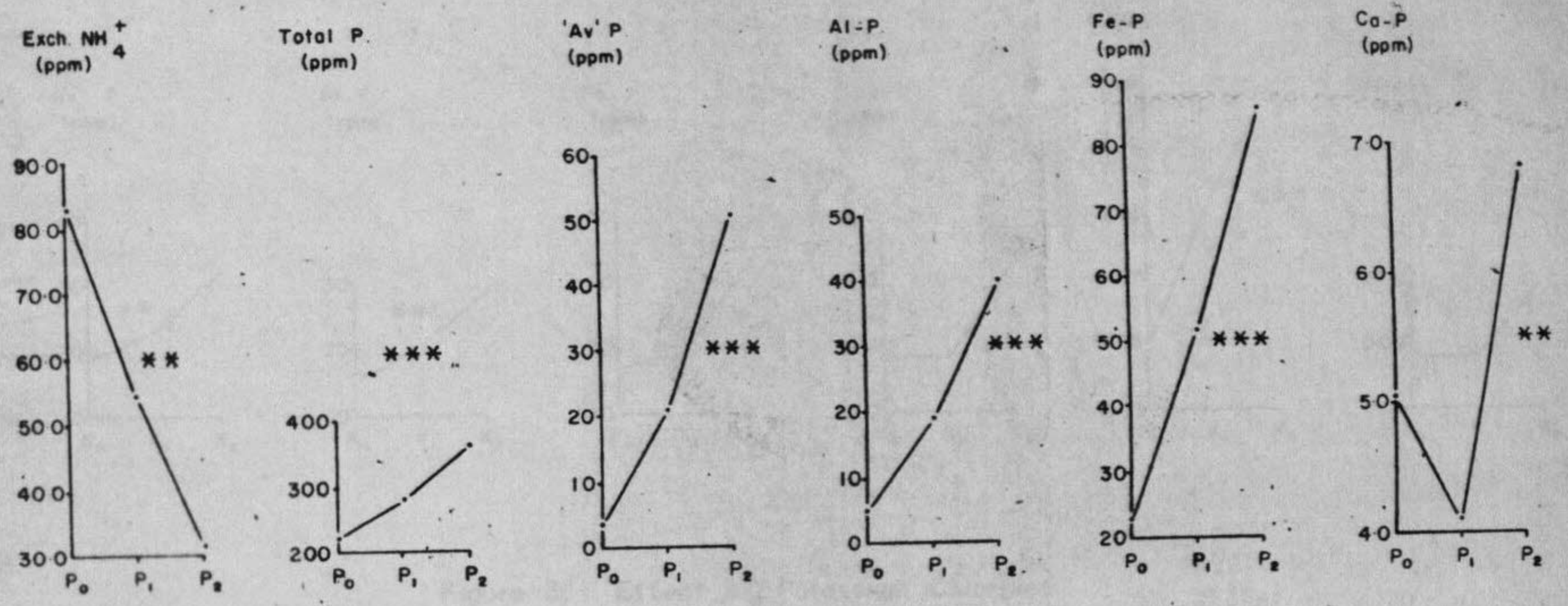

Figure 2: Effect of Mono-Calcium Phosphate

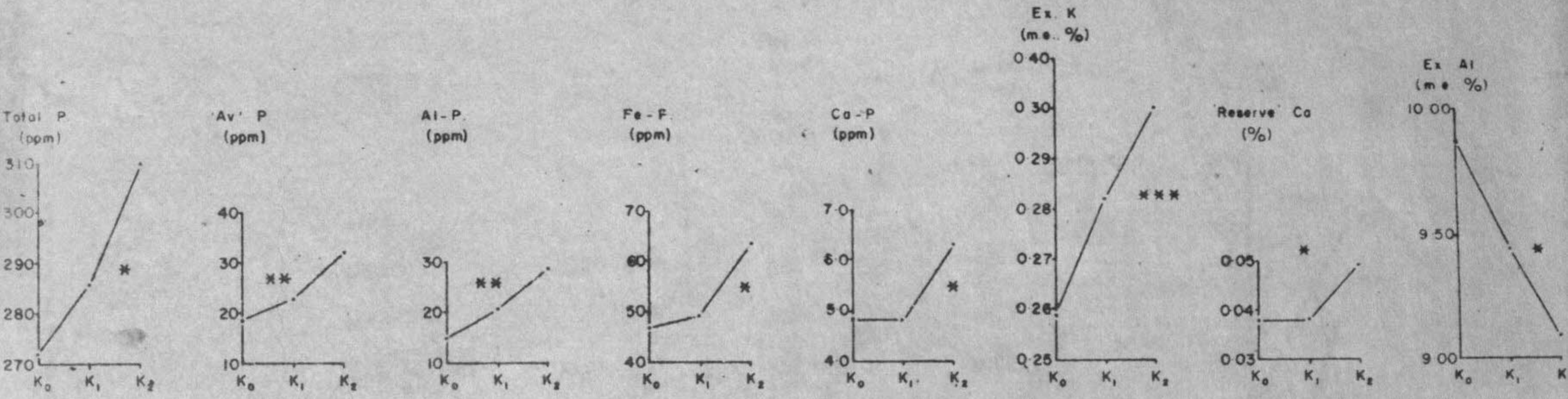

Figure 3: Effect of Potassium Chloride

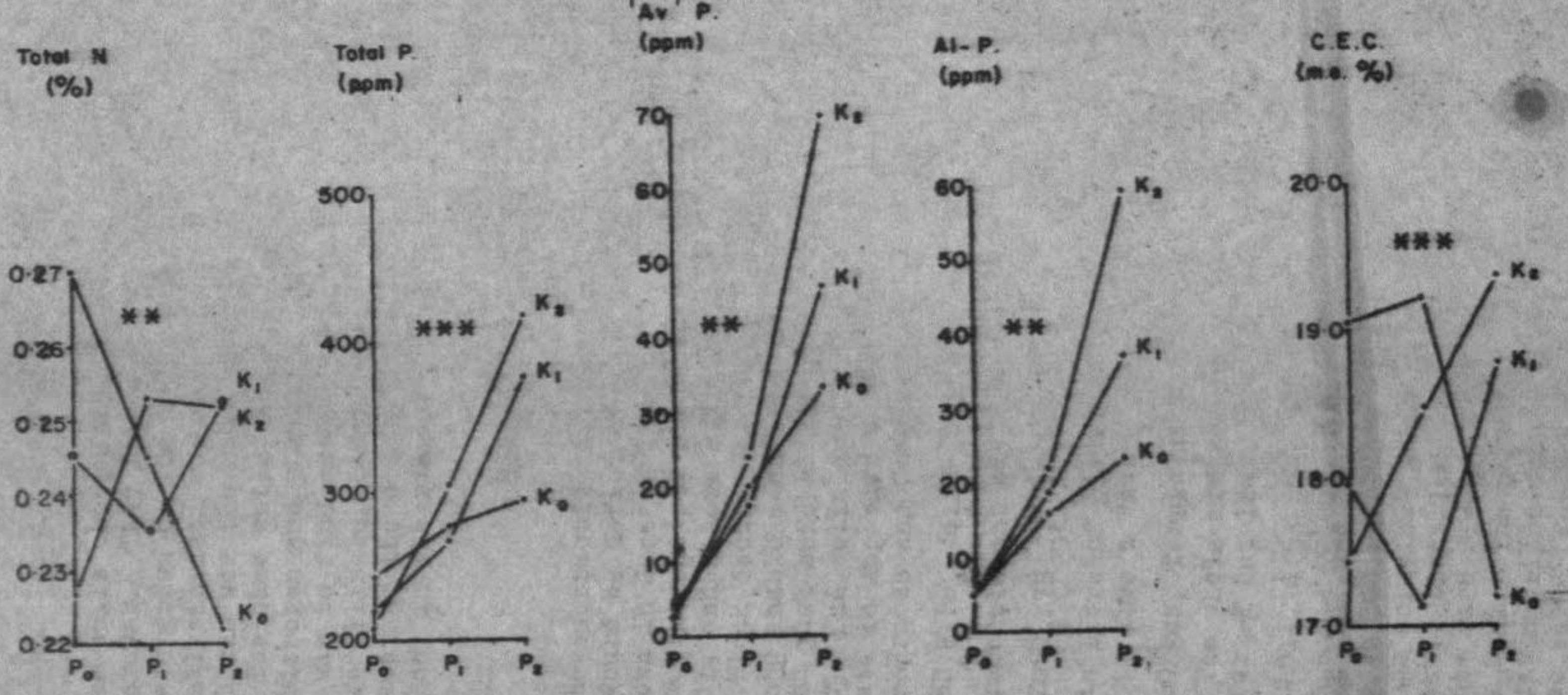

Figure 4: Interaction Between Mono-Calcium Phosphate and Potassium Chloride

LEAF ANALAYSIS FOR ANNUAL CROPS

I. The Effect of Soils and Fertilisers on the Yield of Rice and the Chemical Composition of the Rice Leaves.

by

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Introduction.

The soils chosen for the study represent the major hill padi soils in Sarawak. They have been studied before, Bailey (1962). Hill padi had been grown on the soils, without fertilisers. Grain, growth and soil analysis data was obtained. From this study it was concluded that phosphorus was the most growth limiting element, followed by nitrogen. The same soils were used in the present study and they were all given nitrogen and phosphorus during the experiment. The object of this study was to find out what effects the different soils and the different fertilisers, other than nitrogen and phosphorus, had on the yield of rice and the concentrations of the major elements, also iron and manganese, in the rice leaves just before flowering.

Materials & Methods

The subtractive nutrient technique was used, and because all the soils would be deficient in N & P they were added to all soils. The rice was sown in June in large (18" diameter) earthenware pots, 4 hill each. There was one pot of soil for each treatment and there were 17 soils in all, and 7 were studied in detail. The experiment was of randomised block design and there were sufficient degrees of freedom for error, to enable a satisfactory statistical test to be made. Leaves were sampled just before flowering in October and the rice was harvested in November. The soils are described, together with some chemical analysis data in Appendix A. The four fertiliser treatments were -K, -Ca & Mg, - Traces and Complete: -K included $CaCl_2$, 4.53 gms; $MgSO_4.7H_20$, 5.00 gms; $NH_4H_2PO_4$, 4.20 gms; NH_4NO_3, 2.10 gms and ferric citrate, 0.2 gms; 1ml of a trace element mixture made up of the following:- ($MnSO_4$, $4H_20$, 5.00 gms; $ZnSO_4.7H_20$, 2.00 gms; $Na_2MoO_4.2H_2$, 1.00 gm; H_3BO_3, 5.00 gms; dissolved in litre of distilled water). The whole mixture was made up to 500 mls to give a "stock solution" -Ca&Mg included. KH_2PO_4, 10.00 gms; KNO_{37}, 20.00 gms, ferric citrate, 0.4 gms; and 1 ml of trace elements solution. The whole mixture was made up to 2 litres with distilled water. -Trace as for -K but leave out trace element mixture. Complete KH_2PO_4, 5.00 gms, $CaCl_2$, 4.53 gms; $MgSO_4.7H_20$, 5.00 gms; KNO_3, 10.00 gms; ferric citrate, 0.2 gms; and 1 ml of trace element mixture. The whole mixture was made up to 500 mls. All the solutions were applied at 10% strength, 1 part "stock solution" to 10 parts distilled water. 200 mls to each pot every 2 weeks. Distilled water was given in between when necessary. The nutrients were given 23 times. Heights and visual symptoms were noted every week. The padi was sown on 6/6, it germinated on 10/6 and the first nutrient solution application was given on 18/6. Soil samples were taken (for analysis), prior to the first nutrient solution application. The soil was air dried, sieved through 2 mm sieve and mixed. Total nitrogen was determined by the Kjeldah method, total phosphorus by the method of Fogg and Wilkinson (1958), after digestion with perchloric acid. "Reserve" potassium, calcium and magnesium were determined by a method developed by the author.

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Yield	Leaf		
	K	Ca	Mg
4	2	1	1
3	3	3	3
2	4	4	4
1	1	2	2

The K: Ca, Mg antagonism is well illustrated. Treatment 3 (-Trace Elements) has the same effect on all Factors. Leaving out calcium and magnesium significantly increased leaf potassium. Yield was seriously affected by leaving out potassium and it was interesting to see that trace elements had a significant effect on rice yield at the 5% level.

Conclusion

Excessive calcium and magnesium has a depressive effect on leaf potassium and consequently on the yield of rice. It may be possible with an annual crop such as rice to discover nutrient deficiencies and imbalances by using leaf analysis at an early stage and thus be able to improve the situation.

Table I

Statistical Summary of Results - Variance Ratios and Significance levels.

Determination / Source of variation	Total Yield	Average Yield/ ear	N	P	K	Ca	Mg	Fe	Mn
Soils	5.50***	2.13*	7.74***	0.17	2.26	2.69*	9.33***	1.24	10.45***
Treatments	58.6***	1.00	0.95	0.16	18.27***	12.75***	3.80*	0.83	0.02
C.V.%	21.7	22.3	11.8	48.7	10.3	11.2	45.6	13.2	33.4

APPENDIX A. SOIL ANALYSIS DATA FOR THE 17 SOILS USED TOGETHER WITH RICE YIELD RESULTS

No.	Determination or Yield / Soil	P.P.M O.D. Total P	"Res" Ca	"Res" Mg	"Res" K	Total %N	Total Yield/treatment (air dry gms) -K	-Ca-Mg	-Tr	Complete
1.	Mixed sandstone and Shale soil (Cretaceous)	117	84	1088	1287	0.20	17.53	18.00	18.36	20.39
2.	Shale soil (Cretaceous)	194	233	1067	1932	0.24	15.70	11.01	10.69	11.20
3.	Mixed sandstone and shale (Cretaceous)	132	435	939	1527	0.17	12.10	12.30	6.91	4.61
4.	Shale soil (Cretaceous)	197	148	1563	4652	0.37	16.43	8.49	10.60	16.40
5.	Arkose soil (Cretaceous)	192	169	1663	2623	0.18	10.60	7.80	11.19	13.28
6.	Arkose soil (Cretaceous)	190	148	1919	6066	0.23	8.30	8.37	18.65	11.00
7.	Deep soil on basic igneous rock	368	422	429	453	0.42	5.4	8.35	14.35	14.26
8.	Deep soil on basic igneous rock	271	317	800	2098	0.35	9.49	11.56	8.56	15.60
9.	Shallow Soil on basic igneous rock	252	637	2622	2255	0.44	13.09	14.50	9.85	26.70
10.	Dark grey Shale (Upper Eocene)	291	537	1702	2686	0.34	14.01	18.36	18.71	10.22
11.	Dark grey Shale (Upper Eocene)	143	501	604	1739	0.21	14.21	13.07	12.05	13.90
12.	Shallow shale soil	148	221	660	1753	0.22	15.90	7.02	9.13	18.75
13.	Shallow shale soil	186	166	1318	2431	0.26	5.70	13.50	9.80	11.60
14.	As (1) Sandy shales	94	243	1009	1960	0.12	8.92	16.25	13.86	11.15
15.	Coarse to medium grained sandstones and conglomerates	271	142	882	3283	0.20	1.40	7.20	7.02	5.36
16.	As (15) Sandstones	223	130	1517	5463	0.19	6.63	9.31	11.88	10.94

	Average Yield per year (air dry gms) -K	-Ca-Mg	-Tr	Complete
1	3.51	3.51	2.04	2.91
2	3.14	2.20	2.67	1.87
3	1.73	2.50	1.38	0.66
4	2.35	2.12	2.12	2.73
5	2.65	2.60	3.40	2.66
6	2.08	2.79	2.78	1.57
8.	1.35	2.78	2.87	3.57
9	1.58	2.89	2.14	2.60
10	2.18	2.90	3.28	2.23
11	2.80	3.06	3.12	2.04
12	2.03	3.27	3.01	3.48
13	3.18	2.34	1.83	3.13
14	2.85	2.70	3.27	2.32
15	2.23	2.32	1.98	2.23
16	1.40	1.80	1.40	2.68
17	2.21	2.33	2.38	2.19

APPENDIX B. LEAF ANALYSIS DATA FROM RICE GROWN ON THE 4 TREATMENTS AND THE 7 SOILS

Treatments	-K TREATMENT							-Ca- Mg TREATMENT							-TRACE ELEMENTS							COMPLETE						
Soils	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
N	3.23	1.95	1.94	2.49	2.33	2.18	3.25	3.16	1.94	2.53	2.69	2.4	2.57	3.60	3.30	2.63	2.10	3.41	2.61	2.49	3.02	2.69	2.33	2.07	2.53	2.30	2.32	3.03
P	0.23	0.27	0.27	0.22	0.26	0.25	0.2[illegible]	0.25	0.24	0.24	0.21	0.20	0.19	0.21	0.19	0.30	0.23	0.17	0.20	0.21	0.18	0.21	0.24	0.21	0.18	0.21	0.22	0.22
K	1.29	2.27	2.27	1.66	2.84	1.86	2.77	2.92	2.99	3.41	3.75	3.23	3.26	3.13	2.76	2.89	2.82	3.15	3.30	2.84	2.68	2.75	2.58	3.13	3.10	3.15	2.92	2.69
Na	0.09	0.04	0.05	0.09	0.03	0.07	0.04	0.05	0.04	0.05	0.06	0.02	0.04	0.03	0.05	0.04	0.05	0.05	0.04	0.06	0.06	0.05	0.06	0.05	0.03	0.03	0.03	0.05
Ca	0.81	0.71	0.89	0.66	0.65	0.90	0.79	0.57	0.59	0.35	0.49	0.54	0.63	0.61	0.59	0.61	0.68	0.46	0.60	0.69	0.68	0.67	0.60	0.70	0.52	0.63	0.66	0.61
Mg	0.27	0.01	0.21	0.12	0.09	0.22	0.33	0.02	0.07	0.12	0.06	0.02	0.05	0.27	0.05	0.10	0.23	0.07	0.07	0.01	0.28	0.05	0.07	0.09	0.15	0.05	0.01	0.29
Fe	131	97	113	104	101	95	87	137	92	114	119	116	113	100	111	118	138	108	116	102	94	119	98	104	98	108	112	93
Mn	473	643	463	227	147	86	68	405	529	379	173	120	417	57	224	450	366	229	237	510	45	340	599	349	201	246	494	53

P.P... C.D.

Treatment	- K							- Trace						
Soil / Week	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	N 8.5	N 8.2	N 9.0	N 10.0	N 9.0	N 8.0	N 8.5	8.5	10.5	10.5	9.5	10.7	7.5	9.5
2	N 10.0	N 12.0	N 13.0	N 13.5	N 13.0	N 13.0	W.L 10.0	11.0	11.0	12.7	11.0	11.0	12.0	W.L 11.0
3	N 16.0	N 15.0	N 14.0	N 18.5	N 11.0	N 15.0	W.L 14.0	15.0	16.5	13.0	15.0	13.0	15.0	D.L 11.0
4	N 20.0	D.L 24.0	Y.S 28.0	N 17.0	N 16.0	N 24.0	N 13.0	D.L 19.0	21.0	24.0	21.0	20.0	26.0	19.0
5	N 26.0	D.L 26.0	D.L 29.0	N 27.0	N 27.0	D.L 26.0	Y.S 23.5	Y.T 23.0	D.T 26.0	D.L 27.0	D.+.H. 26.0	N 28.0	D.+. 28.0	22.5
6	Y.S 34.0	Y.S 32.0	Y.S.' 29.0	Y.S.' 35.0	Y.S. 25.0	Y.S. 29.0	Y.S.+e 22.0	Y.S. 30.0	Y.S. 36.0	Y.S.' 33.0	D.L. 32.0	Y.S. 35.0	D.L. 34.0	L 27.0
7	Y.S.' 34.0	Y.S 34.0	Y.S.' 31.0	Y.S.' 38.0	Y.S.' 33.0	b.Y.S.' 34.0	Y.S. 29.0	Y.S.'I 42.0	Y.S.' 39.0	Y.S.' 35.0	Y.S.' 40.0	Y.S.' 32.0	Y.S.' 40.0	Y.S.T.'L 31.0
8	Y.T.&Y.S.' 34.0	D.L.'&Y.S. 33.0	Y.S.' 31.0	Y.S.' 37.0	Y.S. 35.0	b.' 35.0	D.L. 41.0	Y.T. 35.0	Y.T.Y.S.' 40.0	Y.S.' 38.0	Y.S. 41.0	41.0	' Y.+b.S.' 40.0	Y.S.' 38.0
9	Y.S.' 40.0	Y.S.+Y.ST.' 38.0	Y.ST.' 33.0	Y S' 38.0	Y.T. 34.0	Y.ST.' 40.0	Y.ST.' 42.0	Y.ST.+I' Y.S. 36.0	Y.ST.+S.' 43.0	Y.ST.&S.' 37	Y.S.Y.ST. 40.0	Y.S. 43.0	Y.ST.' 40.0	Y.ST.b.' 39.0
10	Y.S.' 40.0	Y.S.'+Y.ST. 38.0	Y.ST.' 33.0	Y.S.' 38.0	Y.T.' 34.0	Y.ST. 40.0	Y.ST. 44	Y.ST.Y.S. +I' 36.0	Y.ST.S.' 43.0	Y.ST.'&S. 37.0	Y.S.Y.ST. 40.0	Y.S. 46.0	Y.ST. 45.0	Y.ST.b. 39.0
11	Y.e.Y.S. 48.0	D.L. 46.0	Y.V. 42.0	Y.e. 48.0	D.L. 46.0	46.0	Y.V. 50.0	Y.ST. 46.0	Y.V. 50.0	Y.V. 46.0	D.L. 46.0	Y.V. 49.0	Y.V. 49.0	Y.V. 39.0

b.l. - burnt leaf. N - Normal. Y.S. - Yellow Spot. Y.S. - Y. spots dying of lower leaf.
Y.T.+Y.S.' - Y - leaf tips dying of lower leaf - Y. spots. Y.e. - Y. leaf edge. Y. spots.
D.L. - Dying of lower leaf. D.+h. - Drying of leaves tips but healthy.

11 WEEKS AFTER NUTRIENT APPLICATION ADDITIONS COMMENCED

- Ca,			- Mg.				Complete						
1	2	3	4	5	6	7	1	2	3	4	5	6	7
9.00	8.0	10.0	9.5	8.0	9.7	9.6	8.7	8.7	11.7	9.2	7.0	10.8	9.0
11.6	13.0	13.0	12.5	11.0	11.0	W.L 9.0	11.5	11.1	12.5	11.6	10.5	13.2	12.3
13.0	17.0	14.0	14.5	15.0	11.0	D.L 13.0	15.0	17.0	13.0	16.0	15.0	14.0	D.L 13.0
19.0	D.L. 25.0	23.0	17.0	18.0	23.0	16.0	20.0	b.e.' 24.0	21.0	19.0	22.0	25.0	15.0
Y.T 23.0	D.L. 27.0	D.T 27.0	N 28.0	D.L. 28.0	28.0	Y.ST. 18.0	N 27.0	D.L. 26.0	D.L. 27.0	N 26.0	' 28.0	D.L. 26.0	L 18.0
Y.S. 32.0	Y.S.' 33.0	Y.S.' 35.0	Y.S.' 28.0	Y.S.' 35.0	D.L. 33.0	L. 19.0	Y.S. 33.0	Y.S.' 39.0	Y.S.' 34.0	Y.S.' 39.0	N 31.0	D.L. 34.0	Y.ST. 24.0
Y.S.' 37.0	Y.S.' 38.0	Y.S.' 39.0	Y.S.' 39.0	Y.S.' 31.0	D.L. 42.0	Y.ST. 18.0	Y.S. 38.0	Y.S.' 38.0	Y.S.' 36.0	Y.S.' 40.0	I.Y.S.' 38.0	b.Y.S.' 39.0	Y.S.b.L. 24.0
Y.T.+Y.S.' 37.0	Y.S.' 38.0	Y.S.' 38.0	Y.S.' 42.0	' 34.0	b.s.' 40.0	L. 20.0	Y.T.+S. 34.0	Y.S.' 40.0	Y.S.' 38.0	Y.S.' 40.0	Y.S.' 40.0	D.L. 40.0	L 28.0
Y.ST.+Y.S.' 40.0	Y.S.' 39.0	Y.S. 39.0	Y.S.' 41.0	Y.ST.' 36.0	D.L. 40.0	Y.S.L. 18.0	Y.ST.+S.' 39.0	Y.ST.' 46.0	Y.ST.+Y.T. 37.0	Y.ST.' 39.0	Y.ST.' 40.0	Y.ST.' 39.0	Y.ST. 30.0
Y.ST.S.' 40.0	Y.S.' 39.0	Y.S. 39.0	Y.S.' 41.0	Y.ST. 40.0	D.L. 42.0	Y.S.L. 19.0	Y.ST.S 39.0	Y.ST.' 46.0	Y.ST.+Y.T. 37.0	Y.ST 39.0	Y.ST. 45.0	Y.ST. 42.0	Y.ST. 31.0
Y.L. 46.0	Y.V. 51.0	Y.V. 43.0	Y.V. 53.0	Y.e. 47.0	Y.V. 46.0	Y.V. 16.0	Y.ST. 46.0	Y.V. 53.0	Y.V. 41.0	D.L. 46.0	D.L. 48.0	Y.V. 46.0	L 34.0

Y.v. - Yellow ven. • - dying of lower leaves. I - Leaf eaten by insect. b - brown spots.
W.L. - Withering of lower leaves. L - loss of green colour.

Even with such a valuable accretion of nutrients so seen, it would appear that the nutrient levels represented indicate values well below normal thresh-hold.

Sample No.		*A 2158	A 2159
Horizon depth.		0"-12"	12"-24"
pH.		4.45	5.70
Organic Carbon %.		0.65	0.07
Total Nitrogen %		0.11	0.02
C/N Ratio.		6.0	4.0
Available P_2O_5., p.p.m.		0.0	1.0
Cation exchangeable capacity, m.e.%.		7.88	1.50
Base saturation %		19	95
Exchange-able Cations. m.e.%.	Ca.	0.70	0.48
	Mg.	0.65	0.32
	K.	0.10	0.04
	Na.	0.07	0.11

Table 2. Chemical analysis of a swale soil. *Dark "organic" topsoil.

7. During the course of the investigation on the raised beach soils it became apparent that the performance of the coco-nut palms on narrow strips of land separating brackish lagoons and the sea was better than on the broader plain areas. A study of an area, near Tuaran, with such a soil distribution indicated that there was a direct correlation between the conductivity of the ground water, which in all cases was obtained within four feet of the soil surface, and the distance between the sea and the inland waters. Soil water samples were taken at median points between the sea and lagoon or estuarine (saline) soils. This is shown in figure 3. The conductivity readings for the sea and lagoon waters adjacent to sampling point 5 was 42.13 millimho/cm and 1.08 millimho/cm respectively. From this it can be seen in this case that a breadth of approximately 450 feet (sampling points 4 and 5) is critical for high sub-soil salinity levels, the soils on wider parts of the stranded beach formation being unaffected by high salinity levels. Thus it appears that saline seepages occur in such soils directly as the result of hydraulic gradients being established by tidal oscillations, and that these sub-soil seepages of saline waters occur for limited distances only. In explaining the better performance of coco-nut palms on the narrower stranded beach formations and also the coastal fringe, therefore, it would appear that nutrients are obtained from the moving ground waters containing high levels of soluble salts.

Mineralogy.

8. Mineralogically, these soils consist essentially of granular quartz. A petrographic study of a soil from the Tuaran area revealed that the soil consisted of subangular and rather elongate quartz grains, ranging in diameter from 0.09 m.m., to 0.27 m.m., and sometimes coated by coloured films. The quartz material comprised 97 per cent of the soil. The remaining part consisted of rounded grains of ilmenite ($FeO.\ TiO_2$), varying from 0.09 m.m., to 0.14 m.m. in diameter. There was no finer earth fraction. With such a mineral assemblage it would appear that the mineral nutrient reserve of such a soil is extremely low.

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Plant cover.		Indigenous grasses	Centrocema pubescens
Sample No.		A 3478	A 3481
Horizon depth.		0"-11"	0"-11"
pH.		5.10	5.50
Organic Carbon, %.		0.35	0.67
Total Nitrogen, %.		0.05	0.11
C/N Ratio.		7	6
Available P_2O_5., p.p.m.		4	5
Cation Exchange Capacity m.e. %.		3.00	3.10
Base Saturation, %		34	40
Exchange-able Cations. m.e. %.	Ca.	0.55	0.83
	Mg.	0.28	0.22
	K.	0.06	0.06
	Na.	0.14	0.13

Table 3. Chemical analyses of two surface horizons of a strand soil, under differing plant covers.

Hydrology.

9. The water relationships of these soils are paradoxical, due to two distinct water regimes being described at differing times of the year. Thus with wet periods poor drainage conditions prevail. During prolonged dry periods, however, semi-drought soil conditions can be expected because of the very low water retaining capacity of these sands. Thus the only soil constantly available for root exploitation is a very shallow zone close to the soil surface which is itself subjected to periodic drought conditions. Attempts to drain these soils have so far been unsuccessful, mainly because of the characteristic physiographic distribution of these soils close to the regional water table. This is shown in figure 1.

Discussion.

10. With our present knowledge it would appear that as far as agricultural development is concerned, the stranded beach soils have a very low potential. At present, no further recommendation for agricultural use can be made other than to their traditional pastural use. Even so very poor grazing is offered with the present type of husbandry practiced, which has resulted in extensive soil degradation giving rise to a poor scrub-type savannah prevailing, and in extreme cases to almost a complete lack of grass cover. These soils are best utilized for urban and its ancillary development, which is obviously limited in scope. It is however instructive to see that these soils are generally concentrated close to the major centres of population. For example in the Papar area there are over 11,000 acres, in Kota Belud area almost 9,000 acres, and in the Tuaran area almost 8,000 acres of stranded beach soils occur. Their distribution in the Kimanis Bay area is shown in figure 2. Over 100,000 acres of these soils occur in the State, almost half of this total occurring on the West Coast Plain alone. There the demand for land is high, and the temptation to embark on expensive agricultural projects always present. It is imperative, therefore, that a answer is found soon as to the best form of agricultural utilisation and hence the efficient use of these soils.

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REFERENCES

Fitch. F.H. Tertiary to Recent Sea-Level Changes and Effect on B. Borneo Physiography. Annual Report, Geological Survey Department. British Territories in Borneo. (1953).

DISCUSSION

Scott: - Do you thus gather the impression that coconuts grow better on these soils where the ground water is saline and, if so, what salinity level appears significant?

Thomas: - The groundwater in these soils are subject to tidal influence and therefore fluctuate. It is not terribly saline and because of this the coconut may take up nutrients from this moving ground water. We have found that with a total soluble salt content of around 0.25% the coconuts seem to perform best.

Andriesse: - Would not split application of fertilizers on these soils be better than single applications.

Thomas: - Yes, in fact, fertilizers are generally split into 3 applications per year.

Watson: - Would not the poor savana type vegetation existing on those soils be an indication of absolute absence of nutrients including trace elements. Would not a fertilizer experiment based on scientific design be useful in giving an idea of the fertilizer requirements of coconuts on these soils.

Thomas: - The chemical and mineralogical examinations indicate that such a state does exist in these soils. Before we embark on such an experiment we hope to benefit from the results of investifations obtained by other workers in Malaysia.

Bailey: - I think the main problem is one of drainage and irrigation. There is insufficient water for crop growth during the dry season. Addition of fertilizer to a dry soil would be dangerous to crop growth. Water table and rainfall data may be of use here therefore.

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Thomas: - Water deficit is a possible problem on those soils during dry periods. Irrigation has been contemplated but these soils are so porous that overhead irrigation would be necessary. This solution, however, would be too costly.

Andriesse: - Similar soils were utilized in South New Guinea by increasing the organic matter content through bringing in the cattle. Paddocks were very heavily fertilised after which vegetables could be grown successfully.

Ng: - The Department of Agriculture, States of Malaya, is carrying out investigations on sandy beach soils along the line of mixed - farming with forage crops under coconut and grazing or stall feeding. But these are only in the early stages of investigation and no definite answers are available yet, other investigations include depth of planting.

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ACID SWAMP SOILS AND PROBLEMS IN THEIR UTILIZATION

by

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Introduction

The rapid and extreme acidification of certain soils was first noted and studied in Holland as early as 1886 by Van Bemmelen (1). The very low pH of these soils were attributed to very acidic iron and aluminium sulphates and free sulphuric acid formed by the oxidation of iron sulphides. Such soils were known in Holland as "cat clay" a name associated with cat's excrement, a general term of abuse for all kinds of poor soils. In Malaya Dennett (2) in 1933 in his preliminary classification and description of the properties of Malayan soils noted that there are cases of soils which have a pH of 3.5 and less, definitely detrimental to plant growth. He stated that this was due to the presence of free sulphuric acid, formed frequently where there are old 'nipah' stumps and similar vegetation containing amounts of sulphur compounds which are subsequently oxidised. This type of acidity he noted nearly always occurred on coastal alluvials but occasionally have been found in quartzite valley areas.

Wilshaw (3) studied the development of high acidity in certain coastal clay soils of Malaya and he inferred that certain soils developed high acidity on drainage and this had serious effect on the growth of plantation crops. He noticed also that freshly dug lumps of clay from the lower depths darkened rapidly from a light blue-grey to near black colour within a space of a few minutes. He attributed this to the rapid oxidation of ferrous sulphide compounds. He analysed some of the soils for sulphate after drying the soils over a period. Sulphate content of some of the soils especially from lower depths 3 to 4 ft. gave a value of 3 to 4.5 per cent and a pH as low as 1.6.

Coulter, J.K. (4) called the acid soils containing considerable quantities of sulphur as "gelam soils". The name being derived from the "gelam" tree (Melaleuca leucadendron) which is characterised by a bark resembling layers of paper and an essential oil (Cajput oil) which may be distilled from the leaves. According to him at a depth varying from 6 to 24 ins. below the surface "gelam" soils smell distinctly of hydrogen sulphide.

Occurrence

Acid soils whether known as 'cat clays' or 'gelam' soils are widely distributed in Malaya especially near the coastal areas; for example at Pulau Gadong, Tanjong Minyak and Duyong in Malacca, Paya Besar near Kuantan, Gual Periok in Kelantan, Kuala Nerus and Batu Rakit in Trengganu and in many other areas some small and some large and others still to be surveyed. Apart from the typical acid 'gelam' areas there are soils which are not so acid to make padi growth obviously bad and uneconomical but which reduce the growth and yield of padi to a considerable extent. These soils contain considerable amounts of sulphur at lower depths which limits root penetration. All the acid soils are characterised by the presence of large quantities of sulphur compounds present which increases with depth. Some of the samples analysed by Coulter showed as much as 6.8 per cent sulphur at a depth of 18-36 ins.

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Formation of Acid 'Gelam' Soils

Since 'gelam' soils are characterised by the large quantity of sulphur contained in them the accumulation of sulphur is at the basis of the formation of such soils. According to Van Beers, W.F.J. (5) the amount of sulphides formed in non-marine sediments is comparatively slight but the sulphur in marine sediments particularly in brackish waters is high. The author has analysed irrigation water and has found that inland waters contained very low quantities of sulphate but on the other hand brackish waters contain a good deal. The source of sulphur therefore is sea water.

The sulphur in brackish water accumulates as sulphide if the environment is highly reducing. Normally iron is present in sufficient quantity in soils to fix the sulphides as iron sulphides. Under Malayan conditions organic matter production in the form of plant life is high and this helps to add organic matter to the soil creating reduced conditions. Further organic matter is not completely decomposed under more or less water-logged conditions but tends to accumulate. This produces soils containing not only high amounts of sulphur but also generally rich in organic matter and sometimes highly acid peaty soils.

Reclamation of Acid 'Gelam' Soils

Since the 'gelam' soils are formed under reductive water-logged conditions which allow the accumulation of sulphur the way to reclaim it is to provide oxidative conditions to oxidise the sulphur to sulphate and wash it out. During the course of this oxidation the soil would become even more acid and would dissolve out the cations like potassium, calcium and magnesium which are already low in such soils. Liming the soil could neutralise the sulphates formed while oxidation is taking place but the formation of calcium sulphate may retard the movement of sulphate since it is only sparingly soluble. In order to study the best method of reclaiming preliminary tank experiments were started by Coulter about 1956.

Experiment in Tanks and Pots

Tanjong Minyak, Malacca, acid soil was put into concrete tanks 1 square meter in area and 3 ft. deep. One row of tanks had sub-soil alone and another two rows of tanks had top-soil 0-12 ins. These were limed at the rate of 0, 1, 2, 5 and 10 tons per acre and subjected to periods of drying and leaching with tap water and rain. Padi was planted but in most cases it either died or made such poor growth as to produce hardly any yields.

In the later part of 1958 the tank experiments were taken over by the author. It was found that inspite of the liming and leaching the sub-soil was very acid pH 2.0 and the conductivity was high. The tanks containing the top soil alone had improved considerably and without lime the pH was about 3.9. This may be attributed to the leaching by rain and tap water. The tanks that received large quantities of lime showed poor distribution of lime. Thus there were soils which showed a pH of 7.2, 0-4 ins. but only a pH of 4.3 about 12 ins. below. The soils were therefore thoroughly cultivated and heavy dressings of fertilizer in the form of calcium cyanamide, fused magnesium phosphate, potassium carbonate (in place of ash popular with farmers in acid areas), trace elements and in some treatments additional green matter was added. The yield of padi produced was just as good as those from ordinary soil. The yields from the tanks receiving 2 and 5 tons lime were just as good as that from the 10 tons.

The tank observations appeared to show that the soil could be improved by drainage alone to a considerable extent. Liming aided in the reclamation but heavy liming resulted in poor distribution of the lime and nutritional troubles which were later diagonised as due to manganese deficiency.

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The uptake of manganese in acid water cultures is suppressed probably by the much larger uptake of iron by the plants. In acid soils like the Pulau Gadong soil manganese concentration is also low and this results in large uptak of iron and corresponding low uptake of manganese. The uptake by padi of manganese in the acid Yen Series is also lower than in other normal soils.

An important aspect of acid soils in connection with the growing of pad is the change in acidity due to water-logging. A pot test with padi with 2 ins. of water gave the following results:-

Time in days	1	12	45	63	80
pH	3.60	3.30	4.47	6.00	6.30

It appears from this that padi can be grown if there is an assured supply of good water and the soil is water-logged long before the padi is transplanted, liming being unnecessary. It is also not advisable to cultivate the soil but just slash any weeds before transplanting as cultivation would bring up sub-soil containing more sulphur.

Field Experiments

Since tank experiments showed that it was possible to grow padi successfully it was decided to try out on a field scale. The area chosen for the tests was a section of the Pulau Gadong Test Station, Malacca. Of the 18 acres acquired for the tests about 4 acres had grown padi successfully and had obtained yields of only about ½ a ton per acre of padi, rather low. Attempts to grow padi in the rest of the area before had failed completely. Part of this area was so poor and barren that Coulter in 1952 described it as follows:-

> "Pulau Gadong Padi Test Station, Malacca, is an area which was once covered with gelam and gelam still exists in the outskirts of the station. A curious phenomena in certain parts of the station is the occurrence of patches, a few square yards in area which are completely bare of vegetation. The surface of the soil cracks and flakes of a hard scale-like material with a greenish yellow colouring form. The area is practically water-logged, the watertable being within 6 ins. of the surface. Pulau Gadong is an example of a former gelam area with a highly sulphurous and sterile soil."

Such a poor highly sulphurous soil was levelled, drainage greatly improved and lime was applied at the end of September 1964. In July 1965 the pH of the soils in various plots receiving different quantities of lime were determined.

Magnesium Limestone powder in tons/acre	0 pH	1 pH	2 pH	0 pH	1.5 pH	3 pH
Fresh top-soil 0-4"	3.40	3.70	3.96	3.49	3.96	4.02
" sub-soil 4-10"	3.40	3.47	3.44	3.39	3.28	3.42
Dry top-soil 0-4"	3.44	3.68	3.82	3.48	3.83	3.99
" sub-soil 4-10"	3.27	3.34	3.48	3.33	3.45	3.38

One and two tons of limestone powder were used for plots which were not peaty and 1.5 and 3 tons for peaty plots. Drainage had improved the pH of the soils as a whole but the liming had only effect on the 0-4 ins. of the soil. The limed plots had better weed growth than the unlimed plots. It has been reported that liming has had little effect on this type of soils and this may be attributed either to, too deep sampling of the soil or due to the soil being cultivated and highly sulphurous soils from the lower depths being brought up.

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It is probable that most of the plots that received lime could grow padi but unfortunately there was lack of suitable water.

Water the Key to Reclamation

The lack of suitable water in acid areas is probably the most important problem in the utilization of the areas. Good irrigation water properly applied could help wash out the sulphur compounds. Besides, water-logging the area in time can reduce the acidity making it possible to grow padi or even use it for fish culture.

In the case of Pulau Gadong it was unfortunate that the water available had a pH usually below 3. The commercial limestone powder required to neutralise the water was determined:-

Limestone powder/water	pH	Conductivity Mhos 10^{-6}
1/100	7.40	1200
1/500	6.10	1200
1/1000	4.85	1150
1/5000	3.20	1400
1/10000	2.90	1600
0	2.75	1600

At the rate of 1 ton of limestone powder to 1000 tons of water it would require a minimum of 3 tons of limestone for about 30 ins. of water per acre for a crop of padi; granting that the rest came from rain. Apart from the cost, the addition of such large quantities of gypsum and magnesium sulphate would give rise to serious problems. In view of this the idea of growing padi was abandoned.

Other Crops

The growing of other crops, especially those which can tolerate acidity, shallow rooting and be adequately supplied by rainfall seems to offer promise. This can only be done after draining the area for some time and liming. However, one method which is usually resorted to is to grow crops on beds made up to more than 2 ft. in height. This helps to oxidise and wash out the sulphur and at the same time keeps the plants above the high watertable and frequent water-logging. Farmers in the Tanjong Minyak acid soil area grow vegetables on high beds and use considerable quantities of ash as fertilizer.

Deep-rooting tree crops cannot be considered as suitable for reclaimed acid areas as it is difficult to remove sulphur compounds from deep layers. As a result tree crops show very poor root system.

Other Uses

A good method of utilizing acid sulphurous areas seems to be to convert them into fish ponds since the soil is perpetually under water the sulphur is in the reduced form and does not cause acidity. Very good yields of fish have been obtained at the Tropical Fish Culture Research Institute at Batu Berendam, Malacca, in ponds situated in acid soils.

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Summary

. The presence of acid soils has been noted in Malaya as early as 1933 and the cause has been attributed rightly to the presence of quantities of sulphur compounds.

. The acid soils mostly occur near the coast as they are formed under brackish water containing sulphur.

. Experiments in tanks showed that small quantities of limestone powder (2 tons/acre) with good drainage could reclaim the soils for padi. Initial heavy fertilizer dressings were required.

. Test in pots showed that acidity is greatly reduced with prolonged water-logging

. Field tests in draining and liming was conducted at Pulau Gadong, Malacca. This showed that lime penetration was very poor.

. Good water availability and proper application and drainage are key factors in the utilization of acid soils.

. Shallow rooted acid tolerant crops could be grown without much difficulty in acid areas.

. Acid areas could be used as fish ponds.

References

. Van Bemmelen, 1886. "Acid Sulphate Soils" by W.F.J. Van Beers, Wageningen, Netherlands 1962, Bull.3.

. Dennett, J.H. 1933 The classification and properties of Malayan soils. M.A.J. Vol. 21, No.8

. Wilshaw, R.G.H., 1940. Note on the development of high acidity in certain coastal clay soils of Malaya. M.A.J. Vol.28, No.8.

. Coulter, J.K., 1952 "Gelam" soils M.A.J. Vol.35, No.1.

. Van Beers, W.F.J. 1962. Acid sulphate soils. Wageningen, The Netherlands 1962, Bull.3.

DISCUSSION

...ley-Birch: - Why did you not use slaked lime? Is it because it is much more soluble?

...apathy: - Ground limestone in Malaya is much cheaper and is readily available. Hence there is very little need to make slaked lime.

...ley-Birch: - When slaked lime is used, however, lesser quantities are needed and it can raise the pH more quickly and higher.

Kanapathy: - We are more concerned with raising the pH of the topsoil to about 1 foot depth for shallow rooting crops and as we are dealing with clays the movement of the calcium through the clays is very much slower.

Bailey: - High sulphide soils are a problem when they are low in iron or when they are drained. If they are low in iron, adding lime will not help the situation because it is more a "sulphide toxicity" problem than a soil acidity problem. Soils low in iron but high in sulphur give more acid soils on draining than soils high in iron. The "sulphide toxicity" problem can be eased by adding iron rich soil as the Japanese do. Lime is only useful when the soils are drained and actual soil acidity develops.

Wong: - In the tank observations where it was observed that the soil improved with drainage, was any observation made to determine the time required to thoroughly leach the soil of the sulphates?

Kanapathy: - Even after 3 years it was observed that a considerable amount of sulphur was present at 30 inches depth.

Thomas: - Work at the Sierra Leone Rice Research Station (Rokupr) has shown that satisfactory pH's can be maintained on certain potential acid sulphate clays, to sustain satisfactory yields of rice. This is done by periodic inundation by sea water. Do these types of soils occur in Malaya? If so has this been attempted in Malaya.

Kanapathy: - We have not been able to introduce sea water onto these soils.

PROBLEM SOILS IN SABAH
BROWN LOAMS AND NUTRITIONAL DISORDERS IN COCOA

by

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SUMMARY

Brown loams derived from basalt and lahars of basaltic composition, and associated with centres of eruption at Mt. Tiger, Bt. Bombalai, Quoin Hill and Mostyn, occur in the Semporna Peninsula. Cocoa planted on these soils has developed symptoms of foliar necrosis and die back after an initial early high yielding period, and subsequently decreasing yields have occured. It is considered that problems of excesses and imbalance of nutrients chiefly manganese and possibly aluminium coupled with low calcium and low pH are involved.

LOCATION OF AREAS

The areas under discussion lie 13 miles to the north of Tawau in the vicinity of Bt. Bombalai and Mt. Tiger, 24 miles to the north east of Tawau, near Quoin Hill and in the Mostyn area fringing the south western apex of Darvel Bay.

PHYSIOGRAPHY

The principal features of the physiography of the Semporna peninsula are shown in map No.1

The brown loams in the Tawau valley lie in the wreck of a volcanic caldera of explosion-collapse type (van Bemmelen 1929, Escher 1930, Williams 1941) of which the following are the principal features:-

a) The rim is formed by the semi circular range of mountains running from Mt. Magdalena Mt. Lucia, Mt. Maria and Mt. Andrassy. Vulcanicity re-occured later at Mt. Maria where a considerable ash cone was established.

b) A large dome of andesitic and dacitic composition lies in the apex of the angle formed by the headwaters of the southern branch of the Merotai Kanan River and Tawau River.

c) Two gently sloping basaltic domes culminating in Bt. Bombalai (1940') and Mt. Tiger (1530').

d) Three microdiorite intrusions forming G. Kukusan (740') G. Batu (+300') and Bt. Gemok (1300') occur N.N.W. of Tawau.

Drainage of the area is by the Tawau river to the south and by two unnamed rivers which coalesce N. of Mt. Tiger to form the Merotai Kanan River.

Their features are shown in Map No.2

The physiography of the Quoin Hill and Mostyn areas has been described by Paton (1962) in his general description of the area and he has also discussed in detail the development of the drainage patterns and the later diversion of the drainage pattern by subsequent vulcanicity. Reference should be made to the original work for details.

GEOLOGY

The geology of the area has been discussed in detail by Kirk (1962) and prior to this, Reinhardt (1924), Reinhardt and Wenk (1951), Collenette (1949), 50, 51, 52, 53), Allen (1952) and Paton (1958 and 1962) have described various parts of the Geology of the peninsula.

The principal features of the geology of the three areas associated with the brown loams are given below.

The brown loams are associated with rocks of basaltic composition at centres of eruption at Mt. Tiger, Bt. Bombalai, Quoin Hill and Mostyn. The present author considers however that some of the soils are in fact derived from mudflows associated with these centres of eruption.

At Tawau basalts were erupted from two centres at Bombalai and Tiger where they form a compact area of about 24 square miles. E. of the Kinabutan Besar a small centre was located by the author in 1952. At Quoin Hill basalt is associated with a centre of eruption at Quoin Hill itself where 18½ square miles of lava occur. At Mostyn both Paton and Kirk have stated that the source of eruption of the basalt cannot be precisely located. There an extensive plateau at moderate altitudes is occupied by the lavas.

Petrologically the basalts vary from dark grey highly vesicular rocksto [illegible]se rockswith phenocrysts of plagioclase sometimes of considerable size and easily noted in hand specimens.

Thin sections show labradorite as the plagioclase present with olivine, hypersthene and clinopyroxene as the other essential minerals. Augite has been seen in occasional sections and where this is found, it is normally the only ferromagnesian mineral present (Kirk 1962). Ilmenite and magnetite are the principle accessories and quartz xenoliths are common both at Tawau and Quoin Hill.

Table I gives a series of analyses from areas at Tawau and Quoin Hill.

TABLE I (After Kirk 1962)

Analyses of Quaternary and Late Tertiary Basalts, from the Semporna Peninsula, North Borneo.

	I	II	III
SiO_2	52.87	54.51	52.57
TiO_2	1.80	1.47	1.70
Al_2O_3	13.69	17.93	15.57
Fe_2O_3	4.82	2.21	4.52
FeO	6.62	6.30	4.97
MnO	0.14	0.14	0.16
MgO	5.76	4.35	5.91
CaO	7.78	7.72	8.14
Na_2O	3.37	3.18	3.50
K_2O	0.75	1.48	1.85
H_2O_+	1.24	0.41	0.88
H_2O_-	1.19	0.13	0.11
CO_2	-	-	-
P_2O_5	0.26	0.48	0.33
Total	100.29	100.31	100.21

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SEMPORNA PENINSULA

SCALE 1:500,000 Approx


Mt. Magdalena
Andesite
Mt. Lucia
Mt. Gelas
Dacite and Andesite
Mt. Tiger
Basalt
MERUTAL
Mt. Maria
Andesite
RIM OF CALDERA
Mt. Bombalai
Basalt
Basalt
Andesite
Dacite
Dacite and Andesite
Mt. Andrassay
Andesite
Mt. Gemak
Microdiorite
Cowie Harbour
Microdiorite
Microdiorite
VOLCANIC MUDFLOWS, NEAR TAWAU,
NORTH BORNEO
SCALE
0 1 2 3 4 5 MILES
VOLCANIC MUDFLOWS
ALLUVIUM
SANDSTONE
X HOT SPRING
GEOLOGICAL BOUNDARY
ROAD
TAWAU
LOCATION MAP
SCALE
SANDAKAN
SULU SEA
Kinabatangan R
Segama R
LAHAD DATU
Darvel Bay
SEMPORNA
TAWAU
CELEBES SEA
SARAWAK GEOLOGICAL OFFICE MAP 138 BY A. W. ALLEN, SOIL SCIENTIST, 1955

Location: I Olivine Basalt Burst Estate Tawau

II Olivine Basalt Western Headwaters of Tawau River

III Olivine Basalt Quoin Hill.

CLIMATE

For the Semporna Peninsula, records of rainfall up to 1957 were available from Semporna, Tawau and Kalabakan only.

The records from Tawau go back to 1906 with several breaks in the record.

Figures from Semporna are continuous from 1936 to the present day with a break from 1939 - 52 whereas at Kalabakan they are available from 1953 onwards

Since 1956, records have been maintained at Tawau Agricultural Station, Apas, Quoin Hill and Mostyn Estate.

It was always considered that the Semporna Peninsula was a low rainfall area averaging about 70" per annum fairly evenly distributed. However the new records are beginning to emphasize what field people have known for some time, namely the extreme variability, and also from the records it is difficult to see any particular rhythm. The Rainfall Statistics (1896 - 1957) produced by the Department of Civil Aviation, Tawau show an average of 78" with a range from 25" absolute minimum to an absolute maximum of 104". In 1963, rainfall varied as follows: Tawau Agricultural Station 69.66", Tawau Apas 81.24", Cocoa Research Station 98.93", Mostyn Estate 104". Similar patterns are observable for previous years.

Wycherley (unpublished report to the Rubber Fund Board, Sabah) has prepare a series of histograms based on median rainfall for Sabah and has discussed the distribution of rainfall in the State on this basis. He concludes that for the south east of Sabah the rainfall is mainly low relieved by local peaks dependent on exposure.

SOIL

T. R. Paton 1962 has surveyed the soils of the Semporna peninsula on a general reconnaissance basis. Further work on the area has been subsequently carried out by Allen, Thomas and Larcer on selected areas. As this paper is concerned with the brown loams at Tawau, Mostyn and Quoin Hill further description will be restricted to these areas.

Paton recognise four series (or sub-families as he calls them) derived from basalt. They are the Table, Quoin, Mostyn and Jarangan series.

Profiles and descriptions of these soils follow:-

Table Soils:

0 - $\frac{3}{4}$: Fine weft of roots mostly fibrous with occasional woody roots with + 20% mineral matter, Root development generally parallel to mull/soil boundary:

Sample No. 6508
$\frac{3}{4}$ - $4\frac{1}{4}$: 10YR 3/2 clay loam: friable: moderate fine nut and granular (60%) with a very fine strong fine crumb structure (40%): Abundant woody and fibrous roots: Boundary diffuse:

Sample No. 6510
$20\frac{1}{2}$ - $71\frac{1}{2}$: 10YR 5/3 clay loam: friable: 10% weak medium and fine nut and granular breaking down completely to a very strong fine crumb: Abundant woody roots:

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Sample No. 6511-12-13

Abundant clear corroded quartz crystals (grit sizes) disseminated throughout profiles.

Location: Field No.7 Cocoa Research Station.

Elevation: Approximately 750' above sea level.

Relief: Gently rolling Slope 3^{o}

Permeability: Very rapid.

Moisture conditions on sampling: Moist.

Drainage: Very freely draining.

Parent material: Volcanic mudflow or basaltic composition.

Railfall per annum: + 90"

Vegetation: 4 years old cocoa 90% canopy. Good litter.

Surface stoniness: Class 0 to 2.

Ground water: Not encountered.

Liable to sheet and gully erosion on clean weeding and only on lenghty exposure to insolation.

Classification: Brown granular loam.

The main feature of interest in these soils is the uniformity of the horizons and the great depth to which they are developed.

On Table Estate depths of over 18' have been penetrated and in one section exposed in the Tawau valley, over 80' of this material is exposed overlying with unconformity a weathered yellowish red horizon grading into basalt.

The horizon between the yellowish red clay loam overlying basalt and the 'soil' is quite clear and abrupt and on the higher slopes of Bombalai the soil thins out and overlies basalt clearly and clearly with no intercalated reddish-yellow horizon.

Mineralogy:

3% Grit fraction clear corroded quartz.
3% Sand fraction: magnetite, ilmenite, quartz.
9% Silt fraction: quartz, magnetite, ilmenite, kaolin, goethite.
86% (Clay fraction: Kaolin dominant:
(gibbsite trace: goethite little:
(quartz trace.
(Amorphous fraction: hydrous iron oxides

Chemistry

Table No 2 gives the results of analysis of the samples taken from the profile and Table No.3 semi-quantitative results obtained on a spectrograph at Rothamsted Experimental Station.

TABLE 2

Analysis of samples

Sample No.	pH	C%	N%	P_2O_5* ppm.	ECE me%	TEB me%	Ca ppm.	Mg ppm.	Na ppm.	K ppm.
6508	5.31	5.07	0.41	247	20.84	11.02	1681	263	28	139
6509	4.82	3.66	0.36	385	16.13	4.04	564	101	19	126
6510	4.84	1.21	0.14	187	10.90	2.51	356	37	20	129
6511	4.82	C.50	0.07	6	8.34	1.95	223	96	22	50
6512	4.92	0.87	0.09	4	10.46	1.98	173	111	18	48
6513	4.92	0.10	0.03	5	11.54	2.88	341	107	19	87

* P_2O_5 extracted with NH_4F at pH 1.8
Values calculated on an oven dry basis (105^o)

Analyst Mrs. Benita Perez-Corpuz, Chemistry Division, Agricultural Research Centre, Tuaran.

TABLE 3

Trace Element Analysis — Semi-quantitative spectrographic analysis

6508	$0-\frac{3}{4}$"	3	100	10	150	300	100	10%	30	100	50	1%	3	80	30	30	5	1%	100	10	1000	200
6509	$\frac{3}{4}-4\frac{3}{4}$"	"	80	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
6510	$4\frac{1}{4}-20\frac{1}{4}$	"	100	"	"	"	"	"	"	"	"	5000	"	"	"	"	"	"	"	"	"	"
6511	$20\frac{1}{4}-47\frac{1}{2}$	"	"	"	"	"	"	"	"	"	"	3000	"	"	"	"	"	"	"	"	"	"
6512	$47\frac{1}{2}-59\frac{1}{2}$	"	"	"	80	"	"	"	"	"	"	2000	"	100	"	"	"	"	"	"	"	100
6513	$59\frac{1}{2}-71\frac{1}{2}$	"	"	"	"	"	"	"	"	"	"	100	"	"	"	"	"	"	"	"	"	"

Analyst Dr. H.H. Le Riche, Rothansted Experimental Station.

thods of analysis were as follows:

pH. 1: 2.5 soil water suspension. Reading taken after 24 hours in a Pye pH meter.

C. Wet digestion procedure after Tinsley.

N. Digestion with sulphuric acid and potassium sulphate followed by steam distillation and titration with standard acid.

P. Extracted with NH_4F buffered at pH 1.8 after 1 minute's shaking and determined as the blue phospho-molybdate.

C.E.R. Leaching with ammonium acetate and steam distillation into boric acid followed by titration with standard acid.

Ca & Mg. E.D.T.A. titration.

Na & K. Flame Photometry.

DISCUSSION

In general the mineralogical picture presented by these soils is a rfectly straight forward one in which material of basaltic composition s weathered under humid tropical conditions giving kaolin and hydrous on oxide as the final clay minerals, the resistant accessories such as artz, ilmenite and magnetite persisting throughout the weathering sequence. e conditions of weathering under high rainfall favour the removal of lcium and magnesium and alkalis from the developing soil thus inhibiting e formation of montmorillonite which could be expected from the moderate ount of MgO and CaO in the original parent material. The cation exchangecapaci the top horizon can be tied in with the relatively high organic matter this top soil (the normal in Sabah is 1.8 to 2.1%) and in the other rizons the values are consistent with kaolinite as the principal clay neral. The distribution of ammonium fluoride soluble phosphate compared th that of carbon suggests that the relatively high figures for the former ements are due to organic phosphate.

The soils are strongly acid in their reaction. Other ratings of ients as shown in the analysis are:-

Nitrogen:	medium in topsoil, low in subsoil
Calcium:	medium in topsoil, low in subsoil
Magnesium:	medium in topsoil, low in subsoil
Potassium:	medium in topsoil, low in subsoil
Sodium:	low to very low.

Trace element distribution apart from extremely high manganese is rfectly straight forward. The very high manganese however is of signici- nce in view of the low reaction.

The most important characteristic of these soils lies in the develop- t of a very strong fine granular and crumb structure, permitting out- nding aeration and drainage conditions, to considerable depth. The rmeability of these soils is such however that in a season of prolonged ence of rainfall, drought conditions can occur in these soils and this uld be regarded as an impediment. This structure however on exposure to solation i.e. under conditions of clean weeding, is irreversibly destroyed, actor which must be taken into consideration in management practice.

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The very rapid permeability of these soils ensures that almost 100% of the rainfall percolates directly through the soil, run off even on moderate slopes being negligible, thus leading to the apparent paradox that in spite of their highly friable consistency they are not liable to sheet erosion. Again however the irreversible destruction of the fine strong crumb structure by exposure of the soil surface will allow clean weeded and insolated areas to suffer from sheet and gully erosion owing to the destruction of the permeability at the surface and the greatly increased surface run off which occurs as a result.

The attributes of this soil are therefore those of a strongly leached strongly weathered tropical brown loam developed on a parent material of basaltic composition with abnormally high manganese.

Quoin Soils.

These soils have not been noted at Quoin Hill or at Mostyn but occur extensively at Tawau on the C.D.C. estates and are in general similar in morphology and chemistry to those of the Table soils. They are redder in colour and addition to kaolinite halloysite has been recorded. They would appear to be a stable phase of the Table series as in general they are developed on gentler slopes to near horizontal surfaces.

Jerangan soils.

These are the most widely occurring soils at Quoin Hill and are generally found to the south and east of the areas showing a development of Table and Quoin soils. Extensive estate cocoa planting has taken place on this soil.

A profile from a cocoa plot at Mile 21½ Quoin Hill road is as follows

0-1½(2"): 10YR 4/3 sandy silt loam: friable: moderate medium and fine nut (60%) and strong fine crumb structure. Diffuse boundary. Abundant woody and fibrous roots.
Sample No. 6501.

2 - 8": 10YR 4/4 heavy silt loam: friable: moderate fine nut and granular (80%) with strong fine crumb (20%). Abundant woody and few fibrous roots.
Sample No. 6502.

8-16" : 10YR 5/5 clay loam: friable: weak medium nut breaking to 80% strong fine crumb and 20% strong fine granular. Very few woody roots.
Sample No. 6503

16-34" : 10YR 5/6 clay loam: friable: Weak medium nut breaking to 60% strong fine crumb and 40% strong fine nut.
Sample No. 6504.

34-58" : 10YR 5/4 clay loam: friable: weak medium and fine nut and granular structure.
Sample No. 6505.
Abundant grit sized angular fragments of clear quartz throughout the profile. Occasional fragments to strongly decomposed felspathie rock occur at 16" becoming common at 34".

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Elevation: approximately 750' above sea level

Relief: flat to very gently undulating.

Permeability: rapid.

Moisture conditions of soil on sampling: Moist.

Drainage: freely draining.

Parent material: basalt with fragments of andesitic ash incorporated in the soil.

Rainfall per annum: ± 70" convectional

Vegetation: 19 months old cocoa under <u>Macaranga gigantifolia</u> shade.

Ground water: not observed.

Surface stoniness: Class O.

Mineralogy: Similar to that of the Table series. No halloysite was recorded from this profile.

TABLE 4

Chemistry

Sample No:	pH	P_2O_5* ppm.	C%	N%	CEC me%	TEB me%	Ca pp	Mg ppm	Na ppm	K ppm
6501	4.46	354	4.71	0.18	9.68	2.18	144	151	15	54
6502	4.68	298	1.19	0.11	9.57	1.59	97	112	14	46
6503	4.45	310	0.56	0.06	7.38	1.44	97	88	27	39
6504	4.55	307	0.27	0.05	5.13	2.57	173	192	15	21
6505	4.72	271	0.27	0.04	3.78	1.27	125	64	15	18

* Extraction with NH_4F buffered at pH 1.8

(Analyst Mrs. B. Q. Perez-Corpuz, Agricultural Research Centre, Tuaran, Sabah)

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TABLE 5

Trace Element

SEMI-QUANTITATIVE ESTIMATIONS. (p.p.m.)

NOS: 6501 - 6505 (Jarangan series)

		Ag	Ba	Be	Co	Cr	Cu	Fe	Ga	Ge	La	Mn	Mo	Ni	Pb	Sn	Sr	Ti	V	Y	Z	Zr
6501	0-1½(2")	3	10	10	3	30	20	7%	20	100	50	300	3	5	30	30	5	1%	80	10	1000	200
6502	2-8"	"	"	"	"	"	"	8%	"	"	"	"	"	"	"	"	"	"	100	"	"	"
6503	8-16"	"	"	"	"	"	"	7%	"	"	"	"	"	"	"	"	"	"	"	"	"	"
6504	16-34"	"	"	"	"	"	"	8%	"	"	"	"	"	"	"	"	"	"	"	"	"	"
6505	34-58"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"

Analyst Dr. H.H. Le Riche. Rothamsted Experiment Station.

DISCUSSIONS

This soil is a strong leached strongly weathered brown loam presenting some striking differences from the Table and Quoin series soils previousl described. In the first place strongly weathered rock material which appears to be andesitic in composition comes in at a depth of 16" and is apparently d to ash which has been incorporated into the soil subsequent to the extrusion of the basalts. The Mineralogy of the soil strongly suggests that basalt is the parent material but again this has not been seen in profiles. The soil does however bear a striking resemblance to brown loams which are undoubtedly derived from early Tertiary basalts in Telupid and they lack the very considerable depth and uniformity possessed by the Quoin and Table series. There are striking differences in chemistry namely that the phosphate status of the Jerangana, although low, is higher than that of the Quoin and Table soils and base status and nitrogen status is considerably lower, as in the case with potassium and calcium also.

In the trace element content, the startling difference between the 10,000 p.p.m. or so of the Table soils and the 300 odd ppm of the Jerangan soil is strikingly evident.

Structurally these soils are similar to that of the Table soils except that at 34" the strong fine crumb aggregates disappear and are replaced by granular and nutty aggregates.

Internal drainage is moderately free but I have noted that after heavy rain, water persists on the surface for several hours in contrast to the Table soils which drain away surplus water almost immediately. Root penetration in Jerangan soils is considerably poorer than in the Table soils being generally restricted to the top 10" only.

These soils therefore, from the chemistry and profile development, are less fertile and structurally less favourable than the Quoin and Table series but lack the considerable quantity of manganese found in the latter two soils.

Mostyn Soils

Paton has described the following profile 3 miles inland from the Kunak wharf near the Kalunpang - Mostyn Road Junction.

0-3" Dark brown 7.5YR 3/2 clay: strong medium granular: friable: slightly sticky: numerous roots: merging to 3-14" Dark reddish brown 5YR 3/4 clay strong medium subangular to angular blocky and strong fine crumb: friable: slightly sticky: small manganese nodules common: some roots: merging to

14-32" Dark brown to dark reddish brown 7.5YR 5 YR 3/3 clay: strong medium subangular blocky with strong fine crumb: friable (buttle)

slightly sticky: very few roots.

On (32 - 60") ditto with abundant large boulders of vesicular basalt.

TABLE 5

Trace Element

SEMI-QUANTITATIVE ESTIMATIONS. (p.p.m.)

NOS: 6501 - 6505 (Jarangan series)

		Ag	Ba	Be	Co	Cr	Cu	Fe	Ga	Ge	La	Mn	Mo	Ni	Pb	Sn	Sr	Ti	V	Y	Z	Zr
6501	0-1½(2")	3	10	10	3	30	20	7%	20	100	50	300	3	5	30	30	5	1%	80	10	1000	200
6502	2-8"	"	"	"	"	"	"	8%	"	"	"	"	"	"	"	"	"	"	100	"	"	"
6503	8-16"	"	"	"	"	"	"	7%	"	"	"	"	"	"	"	"	"	"	"	"	"	"
6504	16-34"	"	"	"	"	"	"	8%	"	"	"	"	"	"	"	"	"	"	"	"	"	"
6505	34-58"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"

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slightly sticky: very few roots.

On (32 - 60") ditto with abundant large boulders of vesicular basalt.

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Vegetation: Thinned primary forest

Elevation: ± 200' a.m.s.l.

Relief: Gently rolling to horizontal.

Permeability: Very rapid.

Drainage: Very freely draining.

Parent material: Lahar material of basaltic composition (Allen).

Rainfall: ± 100" p.a.

Surface stoniness: Class 4.

The present author however considers that only the last series is derived from basalt as a true parent material, the remaining three being derived from mud-flows, a view which is not accepted by Paton or the Geological Survey. An appendix to this paper gives the considered reason for these view.

Nutritional Disorders in Cocoa at Quoin Hill

Symptoms of disorder can first appear as early as 1½ to 2 months after planting but are very much less common on young trees than on old trees. First pods normally appear 18 to 24 months after transplanting and after this stage it is uncommon to find any trees which are not affected to some extent. The Amelonado variety, which is known to have a narrow range of adaptability to varying conditions, suffers very much were from this disorder than some of the other cocoa types.

The symptoms on young leaves occur normally from the time when the young flush leaves are about five inches long till just after they have hardened. Marked marginal and interveinal necrosis occurs to give a typical oak leaved pattern. The necrosis can start in the interveinal areas and sometimes spreads as far as the midrib before joining up along the margin. The young unhardened flush leaves show little preliminary interveinal yellowing and the necrosis spreads from the very fine veinlets. With flush leaves that have become green a broken yellow border occurs which is up to 2 mm broad along the necrotic areas and the oak leaved portion is a higher green than normal. On the new flush leaves this border is a lighter pink than the rest of the leaf. Islands of interveinal necrosis separate from the marginal necrosis occur occasionally.

On the older leaves, symptoms start with a diffuse light green to yellow mottling or spotting of the leaf and are spread evenly over the whole leaf. The appearance of this spotting sets in shortly after the leaf has hardened.

As the leaf ages, some of these spots become necrotic sometimes starting with the very fine veinlets. These necrotic patches eventually spread into large irregularly shaped areas with broken yellow borders. No regular pattern is noted and they can be marginal, interveinal, distal or proximal and can also occur as a broad area of the leaf from the tip or the margin.

Shoot die back and leaf fall also can occur and sometimes the trees can be completely bare, this lasting from a month to three months. Recovery then occurs with new flushes of leaves. Sometimes the bare shoots and branches will produce a profusion of new shoots to give a broom-like effect.

A periodic variation has been noted in the intensity with which these symptoms occur, becoming more marked at the end of yield cycles and following adverse weather conditions.

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The Agronomist at the Cocoa Research Station on whose information the above is based, states that he cannot tie in the above symptoms with any of those described in the literature particularly Maskell et al (I.C.T.A. Report on Cocoa Research 1949-51) and Lockard et al (Department of Agriculture, Federation of Malaya Bull, 107) He considered at first that it may be due to calcium and magnesium deficiency because of symptoms in the early leaves. He however became doubtful of this diagosis on the grounds that the necrosis does not always start on the margins. He did consider at one stage that the interveinal necrosis appeared similar to those described by Lockard but white spots near the base of the lamina and thickened midribs described by Maskell did not occur. The Agronomist did however consider potash deficiency as the areas between spots are a normal green. All these deficiencies agree to some extent with the results of foliar analysis and in particul the strongly acid reaction shown by these soils.

These symptoms appear also on other acid soils of similar derivation at Table Estate (C.D.C. groups) and to a restricted extent on look-see trials on basaltic soils in the Labuk Valley. They however to occur far less frequently at the Tawau Agricultural Station which is on recent soil derived from a mixed igneous rock parentage (i.e. basalt, andesite and decite). The Agronomist at Quoin Hill has also stated that he has noted similar symptoms on areas of the same soil on jungle vegetation and on cover crops in particular. Flemingea congesta.

Summary of investigation on nutritional disorders at Quoin

In 1957, Mr. T.R. Paton then Soil Scientist in this Department draw attention to the manganese status of these soils and had some analyses done to support his statements. He found the following results on the soils under discussion.

Sample No:	Depth	ppm. Mn
	Jerangan Soil	
1063	0 - 1"	260
1064	1 - 14"	196
1065	14 - 26"	190
1066	26 - 52"	190
1067	52 - 72"	280
	Table Soil	
1068	0 - 2"	2160
1069	2 - 12"	1524
1070	13 - 31"	1084
1071	31 - 51"	1328
1072	51 - 72"	1448
	Quoin Hill	
1073	0 - 2"	1350
1074	2 - 14"	740
1075	14 - 25"	648
1076	28 - 72"	196
1077	52 - 72"	196

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In this connection work by Mr. J.K. Cox then Agricultural Officer East Coast in 1952 on the manganese status of leaves showing symptoms of supposed bunchy top disease and healthy leaves is of interest. The leaves showing symptoms of disease ran at 1164 p.p.m of Mn whereas the healthy leaves showed about 200 - 300 p.p.m. of Mn.

In 1960, after the State had spent huge sums of money on bunchy top control, it was decided by Professor C.W. Wardlaw that this disease did not exist in Sabah.

Finally in this a third expert gave attention to this matter concerning a similar soil at Mostyn. Mr. R. Michand Consultant to Socfin Ltd. then advising the Borneo Company in 1959 had an investigation of the nutritional status of oil palm leaves made. He found complete normality in all nutrients with one exception namely that calcium was at threshold status and manganese was high.

In 1961 as a result of a visit by Dr. G.A. Watson head of the Soils Division of the Rubber Research Institute of Malaya, leaf samples from the nursery at Cocoa Research Station were sent to Kuala Lumpur. Dr. Watson thought at the time of his visit that the symptoms, were those of iron deficiency and were caused by an excessive uptake of manganese. Table V below gives the results of these samples:-

Table V

Lab Sample	N%	K%	P%	Ca%	Mg%	Mn ppm.	Fe ppm.
4548	2.48	2.55	.19	.63	.53	1140	193
4549	2.69	2.51	.23	.59	.46	16.0	286

Sample No.4548 showed no symptoms, 4549 showed iron deficiency symptoms.

Dr. Watson in his comments on the results and in commenting on Paton's results states that these results confirm his diagnosis and that although the iron of content of the leaves seems at a satisfactory level, in fact under conditions of high manganese uptake (i.e. low pH) normal metabolism of iron is prevented and a chlorotic condition appears.

He suggested mixing small quantities of ground limestone with the planting soil and simple tests would soon give an indication of the optimum level of lime to use. I notice however that Watson restricted his comments to the symptoms he saw in the nursery. Following this, a further selection of leaves from the field were sent to Kuala Lumpur.

Sample No.	Locality	Soil
3201	Cocoa Research Station ..	Table
3202	" " "	"
3209	Cocoa Plot M. 22½	Jerangan
3210	" " "	"

Wyrley-Birch comments to the effect that the odd numbered samples are of newly hardened flush leaves with green petioles and even numbered samples are of old leaves with completely brown petioles. He also mentions that the weather for the year under review (1960) has been exceptionally dry i.e. 30" less than it should have been and that the symptoms were very strongly developed.

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The results on these samples are given below calculated on oven dry material:

Sample No.	N%	K%	P%	Ca%	Mg%	Mn ppm.	Fe ppm.
3201	2.35	2.50	.22	.34	.41	751	142
3202	2.12	1.74	.11	1.21	.55	3510	214
3209	2.20	1.54	.16	.25	.40	235	163
3210	2.00	0.78	.08	.80	.89	1084	208

Further to this work C.D.C. Estates at Tawau were asked for results of analyses of leaf samples sent to the Chemara Research Station (Messrs Guthrie & Co.) and their results for similar soils confirmed finding above except that a suggestion of K deficiency arrises at Tiger Estate.

In 1965 as a result of a visit by Dr. J.K. Dixon Director of the New Zealand Soil Bureau, an investigation by the Chemist of that organization was carried out into the composition of young and old leaves of cocoa on various soils. The results are given below in full and includes Mr. N. Wells recommendations.

ANALYSES OF COCOA LEAVES FROM SABAH

1. Methods of Analysis

Emission Spectrograph	Ca Mg Na Si Mn Fe Mo B Al Cu Ni Sr Cr Ti Ba
X-ray Fluorimeter	S Cl Zn
Flame Photometer	K
Colorimeter	P
Kjeldahl	N

2. Analysts

Mr. J. S. Whitton, Miss P. Brown, and Mr. N. Well.

3. Published Data

Fertilite 14

element	deficiency symptoms at below:-
N	2.3%
P	.1%
K	1.3%
Ca	.3%
Mg	.3%
Mn	20 p.p.m.
Fe	100 "
B	5 "

Imperial College of Tropical Agriculture, Cocoa Research, 1952.

Site exposed to sea Cl range	.07 to .14%
Cl in scorched leaves	. 2 to . 4%
Na range, unscorched	.07 to .26%

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TABLE 6

Field No.	%										p.p.m.											
	Ash	N	P	K	Ca	S	Mg	Na	Cl	Si	Mn	Fe	Mo	Zn	B	Al	Cu	Ni	Sr	Cr	Ti	Ba
3503	6.1	1.96	.12	1.2	.43	.33	.43	.002	.05	.3	165	43	.03	72	37	360	15.3	1.1	6.4	.15	4	1.5
3504	8.1	1.90	.1	.9	1.2	.30	.83	.007	.03	1.63	1,150	93	.17	33	97	790	51	5.3	84	.92	14	.7
3505	6.7	1.98	.15	1.6	.8	.23	.57	.002	.05	.36	720	27	ND	85	39	250	15.2	10	32	.13	1.6	39
3506	9.1	1.93	.1	1	1.35	.26	.95	.001	.035	1.7	2,230	82	ND	130	82	590	77	26	175	1.4	6.4	53
3507	6.3	2.09	.2	1.1	.95	.26	.76	.001	.035	1	690	63	.25	78		300	17.5	7.6	195	ND	4	4.4
3508	14.2	1.99	.12	.5	2.05	.18	1.5	.005	.045	3.1	1,900	48	.23	92	116	280	11.3	15	270	ND	5.1	99
3509	7.2	1.95	.16	1.2	1	.22	.68	.003	.045	1.15	960	29	.37	82	65	147	15	5.8	120	.35	1.5	42
3510	13.3	1.68	.16	.6	1.85	.31	1.3	.004	.05	2.7	2,100	23	.4	140	90	220	14.5	11.3	270	ND	1.6	76
3511	7.1	2.11	.15	2.3	1.35	.21	.67	.004	.06	.53	130	130	.48	58	55	430	27	4	17	ND	6.2	13
3512	11.3	2.01	.1	.86	1.75	.23	1.13	.009	.08	2.1	420	32	.94	18	81	1,350	12.4	6	54	ND	54	27
01418	7.0	1.55	.18	1.3	1.1	.26	.77	.001	.015	1.2	380	36	.14	48	59	165	17	18	105	.73	1	41
01419	10.7	1.91	.11	.9	1.7	.26	1.1	.001	.02	2.3	450	20	.33	78	58	145	12	32	165	ND	.7	63

Analyses of Cocoa Leaves from Sabah

Analyses by J.S. Whitton, Miss P. Brown, and N. Wells.

4. Differences between young and old leave.

Analyses are enclosed in a Table.

Young values greater than old values for N, P, K, Mg (Na)

Young values less than old for Ca, Si, Mn, Mo, B (Al, Cu), Ni, Sr, Ti, Ba

Young and old values irregular S, Cl, Fe, Zn, Cr

5. General interpretation of results

Low values	N, P, K, Fe, Na, Cl, (Mo, Zn)
High values	Mn

6. Interpretation of results on a soil basis

Jerangan soil, unfertilised, very poor cocoa.

N	deficiency level
P	deficiency level, young leaves only slightly than old leav
K	deficiency level
Ca Mg	low compared with other samples
Mn	Very high values in older leaves
Zn	May be too low

Nos. 3505/6

Table soil, chocolate basalt, unfertilised, poor cocoa.

N	Deficiency level
P, K	average
Mn	extremely high in older leaves
Mo	very low
Fe	very low in young leaves

Nos. 3507/8

Balung alluvial soil, fertilised, good growth of cocoa. Gleyed recent soil derived from alluvium of mixed igneous rock parentage.

N, P	slightly better than most of the other samples
K	More deficient than other samples
Mn	High in older leaves
Mg, Ca, Sr,	very high
Cr	low

Nos. 3509/10

Table Family at Quoin Hill, fertilised, good growth of cocoa.

N, K	below average for samples
P	above average for samples
Mn	extremely high in old leaves and high in young leaves.
Mg	very high
Fe	very low

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Nos. 3511/2

Semporna soil, unfertilised, poor growth of cocoa.
Soil developed on limestone.

N, K	values highest for the group
P	values average
Mg	above average
Mn	below average
Mo	above all other samples
Zn	deficiency level
Cr	very low

Nos. 1418/9

Recent alluvial soil, unfertilised, good growth of cocoa.

N, K, Mg	average for the sample
P	above average
Na, Cl	very low
Fe, Mn	values are low

7. Discussion of result

The Jerangan soil gave cocoa leaves with deficiency levels of three major elements, N, P, K. If these are corrected it would be prudent to then check Zn, Ca and Mg levels by plant analysis. High levels of Mn may be causing Fe to be unavailable.

The Table soil, chocolate basalt, had N at a deficiency level but P and K were better than for the Jerangan soil. Extremely high levels of Mn again might be giving unavailability of Fe, this is very apparent in the younger leaves. Mo may not be essential for cocoa but this would be the place to try it.

The Balung soil has been fertilised and the N and P values are better than at most of the other sites; however this has resulted in lower values of K than in the other samples. Most other elements are at reasonable levels although again high Mn may be giving low Fe in the leaves.

Table Family at Quoin Hill looks as though addition of P as fertiliser has resulted in rather low values for N and K. Mn levels are extremely high and may be giving lower values for Fe.

The Semporna soil gives cocoa leaves with above average values for the major elements, this would imply that another factor is limiting growth. e.g. soil pH or a trace element. It is suggested that Zn be tried, also Mn could be used but its values is well above the deficiency level quoted. If a response to Zn is obtained the major elements would require more analyses.

The recent alluvial soils, although unfertilised, has a P level in cocoa that is close to that on the fertilised soil at Quoin Hill. Most other elements are average in value but Na and Cl are at their lowest and both Fe and Mn are also low.

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3. General approach

(1) Soils other than Semporna

This concerns the order of tackling the problem -

Raise N

Raise P

Check for K levels, raise if low

Try Fe, Zn, B.

(2) Semporna soil

Raise Zn

Check major element levels

Check other trace elements Mn, B.

These are the basic chemical results which have been obtained to date for this disorder developed on these soils.

Mr. E. A. Wyrley-Birch the Cocoa Agronomist Sabah is with you today and will give you an outline of the agronomic work done to try and overcome this state of affairs. Your comments on this paper and his work will be most welcome to the Department.

DISCUSSION

Shao: - I would like to add that from our analysis, the leaf samples collected from Quoin Hill and Jarangan are high in Al, low in Ca and Mo. Al contents for samples collected from Tiger Estate are also high but the pH of the Tiger soils is around 6 as compared with 4 for both Quoin Hill and Jarangan soils. I must say that these results are preliminary and we would certainly lock into this problem further.

Kanapathy: - It does appear that die back is due to some effect on the root system. Low pH, Al toxicity, lack of P, alternate wetting and drying of the roots and effect on the root system by pathogens etc. All these affect the roots and die back may be due to any one or a combination of these.

Bailey: - Soils with high aluminium have a high buffering capacity. Removal of free aluminium by EDTA, or some other means - e.g. silicate may help. If the roots are damaged the water and iron cannot get in. I suggest that the problem is centred in soil near the roots - may be it is "Physiological drought" caused by root damage. This root damage could be caused by high Al^{+++} or Fe^{++}, Fe^{+++} concentrations. Direct measurements of these by Redox (Pt. & Calomel & Electrodes) should be made not just pH.

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